Ministry of
Transportation and
Communications
Ontario

MI-80

POTENTIAL USE OF GRANITE CURB FOR HIGHWAY CONSTRUCTION IN ONTARIO

MATERIALS INFORMATION REPORT NO. 86

POTENTIAL USE OF GRANITE CURB FOR HIGHWAY CONSTRUCTION IN ONTARIO

by

C.A. Rogers

ONTARIO
MINISTRY OF TRANSPORTATION AND COMMUNICATIONS
ENGINEERING MATERIALS OFFICE
SOILS AND AGGREGATES SECTION
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ROGERS, C.A., 1985; Potential use of granite curb for highway construction in Ontario; Ontario Ministry of Transportation and Communications, Engineering Materials Office, Report MI 86, 82p., October.

SUMMARY

PROBLEM STATEMENT

It is normal practice in Ontario to use concrete curb on bridge sidewalks, and concrete curb and gutter at selected highway locations. The concrete is exposed to frost action and to the abrasion and impact of snowplow blades. Deterioration due to these agents is common, especially in northern regions. Outright failures of concrete curb are experienced from time to time. These failures are unsightly, and repair becomes a tedious maintenance task.

There is a need for a more durable and cost effective material for curbing.

POSSIBLE SOLUTION

Substitute GRANITE CURBING for concrete curb and gutter at selected locations. Granite is unaffected by frost action, and is extremely resistant to the impact of snowplow blades.

AVAILABILITY

There are five potential suppliers of granite curbing in Ontario. Working quarries are located in Northwestern, Northern, Central and Eastern Regions.

WHO USES GRANITE CURBING

At least nine highway authorities in northeastern North America make extensive use of granite curbing. Vermont, for instance, reports that they have not replaced a granite bridge curb in over thirty years of use.

RECYCLING

Granite is nearly indestructible in the highway environment. When a highway or bridge is reconstructed, it is normal practice to salvage the old curb, and use it in the new construction.

COST

Concrete curb and gutter had an average cost of about $49/m in Northwestern Region for the years 1980 - 1983. The estimated cost for supply and installation of granite curb is about $53/m. When the extremely long life of granite curb is considered, the cost per year is substantially less than that for concrete.

RECOMMENDATIONS

The benefits of using granite curbing in place of conventional concrete should be assessed fo each bridge rehabilitation and highway reconstruction job.

ACTION SO FAR

The M.T.C. New Products Committee has endorsed the use of granite curbing on bridge decks.

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POTENTIAL USE OF GRANITE CURB FOR HIGHWAY CONSTRUCTION IN ONTARIO

INTRODUCTION

IN 1976, M.T.C. experienced severe freeze-thaw deterioration of concrete curb and gutter on Hwy. 11 at Burks Falls. This concrete had been placed the previous year. local gneissic and granitic gravel aggregate was used, typical of the gravel found in large areas of Northern Ontario. The deterioration (Figure 1) was sufficiently severe that a considerable effort has been devoted towards the study of this problem. The Engineering Materials Office has spent a good deal of money on testing directed towards trying to make durable concrete with these aggregates. After seven years, we are still not able to substantially and consistently improve the quality of concrete using these aggregates.

Unfortunately, the experience at Burks Falls is not an isolated example. Occasionally, M.T.C. experiences failures of concrete curb and gutter placed the previous year. failure is due to frost action. This, in turn, may be caused by lack of proper air-entrainment, high water-cement ratio, and/or the use of aggregates that promote scaling. These failures are found throughout Ontario, but are more prevalent in the north. The extremely severe climatic conditions, combined with the use of aggregates susceptible to scaling, and the occasional long delay between mixing and placement, results in difficulty in making durable concrete.

A possible solution to this problem is to substitute granite curbing for concrete. This approach is used by many highway authorities in North America, who report excellent performance.

GRANITE CURB

Granite is a strong (130 MPa), durable building stone, unaffected by the action of frost, and extremely resistant to the impact and abrasion of snowplow blades, Granite curbing is made in a variety of sizes, shapes, and finishes, depending on the required use:

> Highway curbing and edging of variable lengths greater than 1m, typically with a section of 150x400 or 450mm.
>
> Bridge deck sidewalk curb of variable lengths greater than 1m, typically with a section of 150x250mm.

Highway curbing and edging usually has a rough rock face which is the natural broken surface of the stone. Curb stones are set vertically with the lower 250-300mm in a well compacted gravel bed. There are two methods for laying curb at tight curves: a curved granite curb, cut by hand, is placed as above. Alternately, straight curb is laid with radial joints. Inspection is a simple task, the greatest anticipated problem being to ensure that the gravel is properly compacted to prevent subsequent settlement and that proper drainage is provided to minimize frost heaving. Mr. C. Nelson, of Nelson Granite, anticipates that granite for this application can be hand split in Vermilion Bay for a cost of $33 - 40 a metre.

Bridge curbing usually has a natural broken or hammered exterior face. The top, bottom, and back are usually saw cut to give a smooth surface. The curb is set at the correct elevation with with temporary wood wedges, and held in place with mortar. The back of each curb is anchored to the concrete with two galvanized or epoxy-coated steel bars. Mr. Nelson anticipates that the cost of this curb should not exceed $66 per linear metre.

Granite curbing is specified and used by many highway authorities in northeastern North America (see Appendix 4). The data in this appendix show that granite curbing is viewed with favour on the basis of both cost effectiveness and aesthetic grounds. The estimated life of granite curbs is at least sixty years (see Appendix 3). Vermont has not replaced a granite bridge curb in over thirty years of use. New Hampshire reports that granite curbing is nearly indestructible. The excellent durability of granite leads to the practice of salvaging old curb during highway and bridge reconstruction. It is then replaced prior to repaving. The long maintenance free life, and ability to recycle it, is considered justification for the sometimes higher, initial material cost. A study conducted by the Centre de Recherches Industrielles due Quebec (Appendix 3) showed that, over a fifty year life, granite curb had an annual cost of $0.21 per linear foot, as compared to poured concrete curb at a cost of $0.84 per linear foot. It is worth noting, however, that they estimated the effective life span of poured concrete curb to be five years, which is unrealistic when applied to our experience in Ontario.

The Estimating and Engineering Claims Office of M.T.C. has conducted a brief analysis of the cost of concrete curb compared to granite curb in Northwestern Ontario (see Appendix 2). Concrete curb and gutter had a weighted average cost of about $49/m for the years 1980 - 1983. They estimated that the cost of supply and installation of granite curb would be about $53/m. There may be a slight additional cost using granite curb, due to the need to extend granular base and hot mix pavement out to the curb, in place of concrete gutter.

On those M.T.C. contracts which are far removed from ready mix plants, and which call for small quantities of concrete, the initial cost of granite may well be less than that for concrete curbing, especially when the costs of inspection and testing of concrete are also considered. The relatively short life of concrete curb also favours the use of granite.

One potential problem with bridge decks curbing is worth noting. In a study of bridge deck leakage in Maine, Smith (1972) found deterioration beneath granite curb on an interstate bridge. This was attributed to seepage of water and dissolved chlorides beneath the curb and mortar. He concluded that 'the joint where granite curb meets bituminous paving opens up from differential thermal contraction in cold weather, the bond weakens between air-entrained mortar and smooth granite, and flashing becomes brittle'. Also, 'contraction joints in curbs must be sealed from chloride and calcium leakage onto top flanges'.

CONCLUSIONS AND RECOMMENDATION

Granite curbing is a strong, durable, aesthetically pleasing material. It is unaffected by freezing and thawing, and able to withstand the impact and abrasion of snowplow blades. It is low maintenance substitute for concrete curbing. Granite may be recycled during highway reconstruction. It may well be cheaper, in the long term, to use granite in place of concrete curbing at selected locations.

The benefits of using granite curbing in place of conventional concrete should be assessed for each bridge rehabilitation and highway reconstruction job.

ACTION SO FAR

The M.T.C. New Products Committee has endorsed the use of granite curbing on bridge decks.

In 1982, the Ontario Geological Survey retained a consultant to conduct a market study for building stone in Northwestern Ontario. Their report was published in January 1984 (see Bibliography). One of the consultants' suggestions was that the Government of Ontario should conduct 'Life Cycle Costing' when choosing construction materials. Life Cycle Costing should consider the initial cost, maintenance and replacement costs, and salvage value over a determined life cycle to establish the real cost of the material.

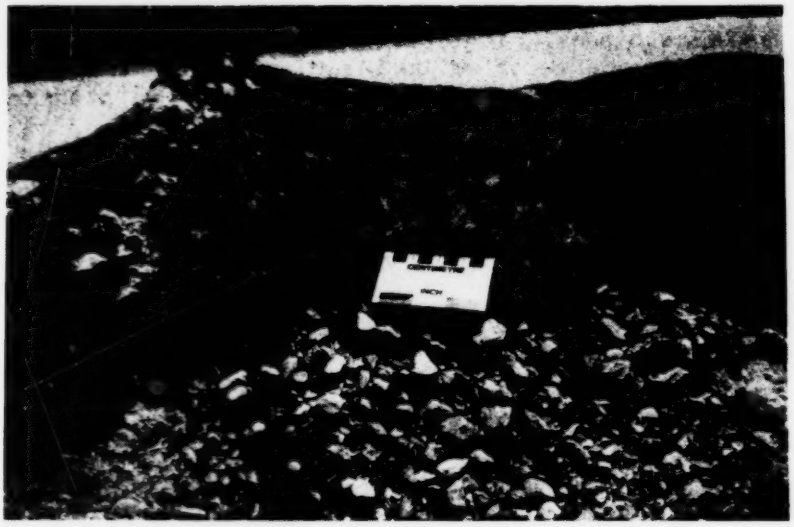


FIGURE 1 Severely deteriorated concrete curb. Appearance after four winters. Deterioration is due to frost action.

FIGURE 2 Granite bridge deck curb, New York Thruway.

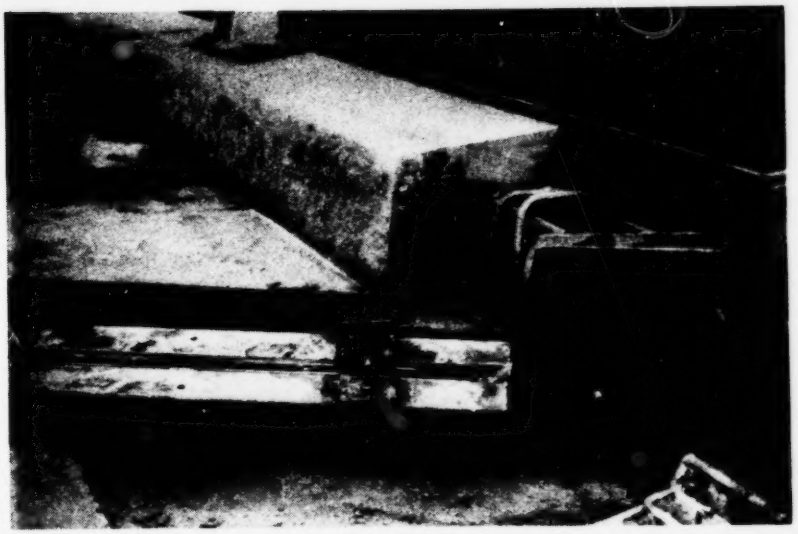
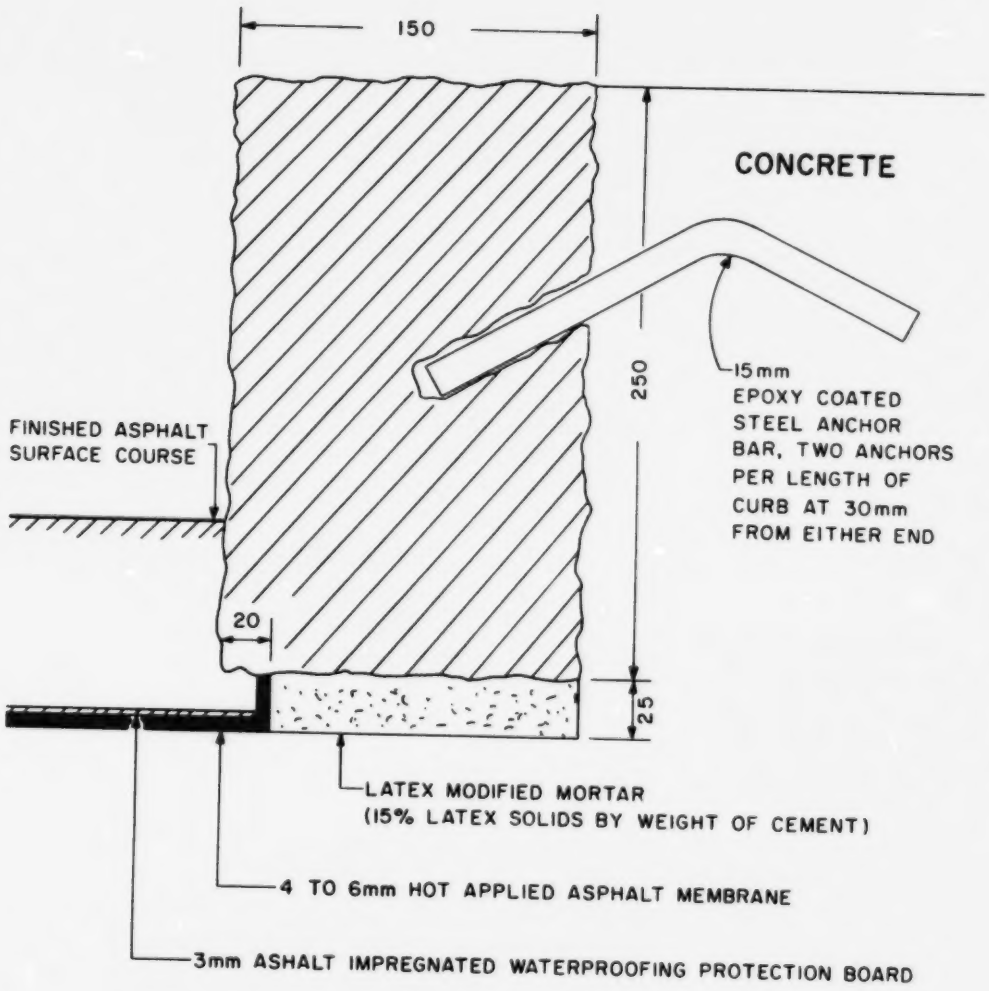


FIGURE 3 Granite bridge deck curb, installation adjacent to expansion joint, New York Thruway.

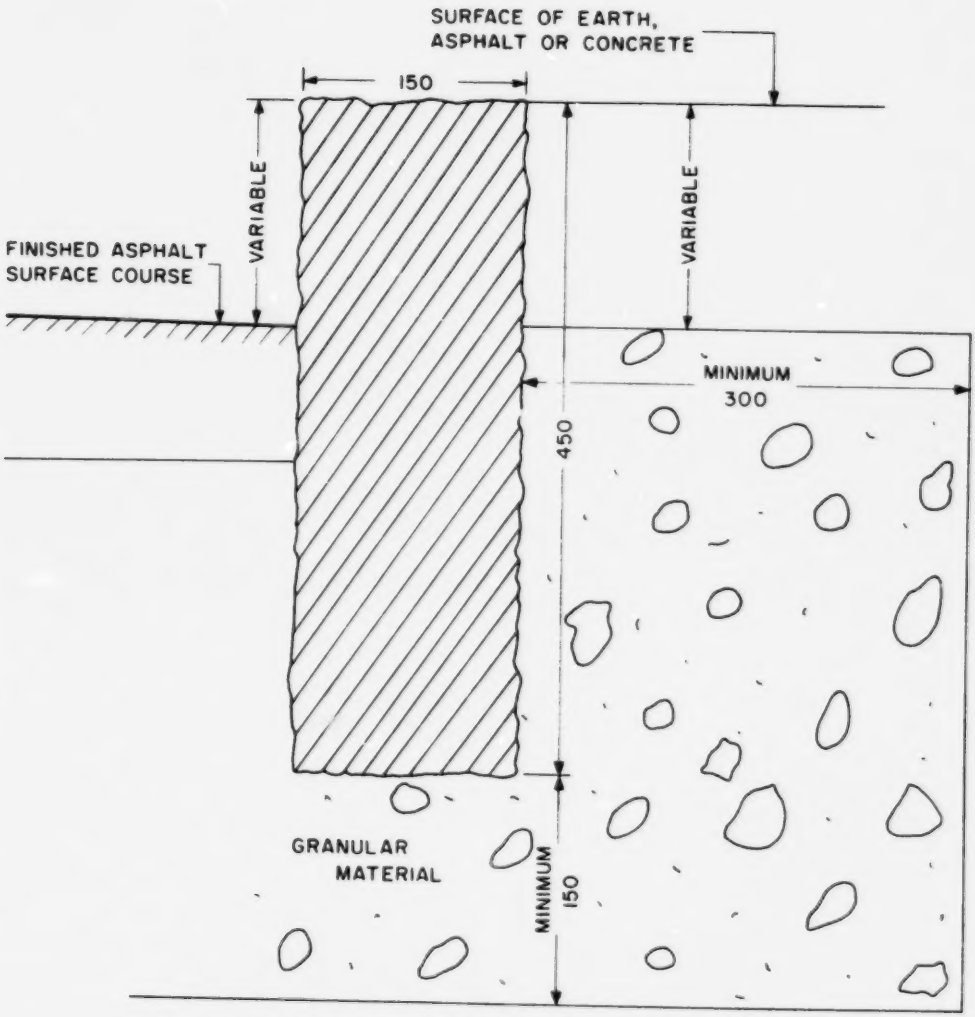
FIGURE 4 Granite bridge deck curb, curb installed prior to bituminous overlay, New York Thruway.



NOTE DIMENSIONS IN MILLIMETRES

SUGGESTED DETAIL FOR INSTALLATION OF GRANITE CURB ON CONCRETE BRIDGE DECK

FIGURE 5



NOTE ALL DIMENSIONS IN MILLIMETRES

SUGGESTED DETAIL FOR INSTALLATION OF
GRANITE CURB ON HIGHWAY EDGE

FIGURE 6

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Storey, C.C., 1983: Preliminary Report of the Building and Ornamental Stone Inventory, Kenora and Rainy River Districts; Ontario Geological Survey, Open File Report 5446.

Winkler, E.M., 1975: Stone, Properties, Durability in Man's Environment; Springer-Verlag, New York, 2nd Ed.,
An excellent publication on properties of granite and other natural stones.

POSSIBLE SUPPLIERS OF GRANITE CURB IN ONTARIO

(1) Nelson Granite Ltd.
P.O. Box 178
Vermilion Bay
Ontario POV 2VO

Contact: Carter Nelson (807-227-2650)

(2) Universal Granite Centre (1976) Ltd.
Vermilion Bay
Ontario POV 2VO

Contact: Bill Rollins (807-227-2108)

See Hewitt (1964, p.44)
NOTE: Both the above producers work adjacent properties, and produce a light red coloured granite sometimes known as 'Morning Rose'.

(3) Dana Black Granite Ltd.
P.O. Box 1992
Sturgeon Falls
Ontario

Contact: L. Maillous
NOTE: This company produces a black granite know petrographically as anorthosite.

(4) Fairmont Granite Ltd.
P.O. Box 60
Beebe
Quebec J0B 1E0

Contact: Sandy McFarland or Bill Archer (819-876-2745)
NOTE: This company operates a pink granite in Belmont Township, north of Havelock, Ontario. See description in Hewitt (1964, p.23). This stone is known in the trade as 'Wild Rose'. Fairmont Granite also operates a deposit in Storrington Township, 18 miles north of Kingston. This material is currently shipped to Japan.

(5) Warren Industrial Feldspar Company Ltd.
2008 LaSalle Boulevard
Sudbury
Ontario P3A 2A5

Contact: Ed. Rose (705-560-0343)

APPENDIX 1

A PROPOSAL FOR THE USE OF GRANITE CURBING IN ONTARIO BY R.C. BEARD, MINERAL RESOURCES CO-ORDINATOR, M.N.R., KENORA

A PROPOSAL FOR THE USE OF GRANITE CURBING IN ONTARIO.

INTRODUCTION

The Northwestern Region (MNR) is currently carrying out a program to encourage and assist in the development of an expanded stone industry in the Region. While investigating the various uses of stone, particularly granite, a situation has come to the attention of our staff that we feel could offer significant long term benefits to the Province.

Preliminary investigations have revealed that, in general, the deterioration of concrete bridge curbings and certain other highway applications, due to salt damage and the freeze/thaw cycle, often results in exceptionally high maintenance and replacement costs. Discussions with M.T.C. staff confirm that this is indeed a serious problem in many parts of Ontario. Our research has further revealed that many jurisdictions having similar climatic conditions to Ontario have, to a significant extent, alleviated this problem by adopting a policy of using granite for bridge curbing and similar highway uses.

The purpose of this submission is to bring this situation to the attention of senior management of relavent Ontario Ministries, and to offer a solution to the problem which would, we feel, result in long term cost benefits to the Province from greatly reduced bridge maintenance costs. The experiences of other jurisdictions in alleviating this problem will be described, with cost figures and comparisons provided wherever possible.

The responsibility of selecting construction material for highway use is obviously not the responsibility of the Ministry of Natural Resources. Our interest lies in the fact that, if this construction technique were adopted in Ontario, it would greatly facilitate the development and expansion of the stone industry in the Province, an important mandate of this Ministry.

THE PROBLEM

The problem of deterioration of conventional concrete highway structures in northern climates such as Ontario is well known. The chemical attack of salt solutions, repeated freezing and thawing, and the constant chipping away by snow plow blades quickly takes its toll of many concrete highway structures. This results in very high maintenance and replace costs. Discussions with local M.T.C. staff and correspondance with highway departments of other jurisdictions, much of which is summarized in the following, confirms and provides evidence of the truth of this fact.

In the Kenora area, it is apparently not at all unusual to have to start repair work on bridge curbs after as little as five to six years and somtimes even less. Replacement after ten to fifteen years is reportedly common. (M.T.C. pers. comm.)

The Quebec Ministry of Transport advises that "poured concrete (curbing) must be replaced after a period of twelve years and prefabricated concrete curbs have to be replaced in approximately eighteen years." (Appendix "A")

Little specific data on maintenance costs were provided by the other jurisdictions, but figues for Ontario could probably be retreived from M.T.C. records if required. However, maintenance costs related directly to curbing repairs are apparently often buried in overall bridge maintenance costs, making retreival difficult. It was also noted that it was often difficult for contractors to bid on curb repairs since concrete deterioration is often hidden and the full extent of the problem often does not come to light until work is started. This no doubt leads to higher tendering costs.

A SOLUTION

A number of jurisdictions in northeastern North America appear to have found a solution to this problem. Information received from some of these jurisdictions (attached as appendices to this submission) reveals that Quebec, New Brunswick, Vermont, Maine, New York, and New Hampshire all have a policy of using granite curbing for certain highway uses where concrete deterioration is a problem. The Province of Ontario, although having a climate similar to the above, is notable for its absence in making use of this durable, long lasting alernative to concrete.

The use of granite curbing by these other jurisdictions is summarized below.

The State of New Hampshire Department of Public Works and Highways reports (Appendix "B") that they use granite largely for curbing, with some also used as ornamental facing on bridge abutments and on retaining wall structures. Curbing is used on bridges, highway interchanges, and along urban routes. It is noted that for granite curbing maintenance costs are almost negligible, it is almost indestructable, and can be salvaged for reuse. Statistics provided indicate that in 1980/81, they tendered over 121,000 linear feet of granite curbing, 21,000 feet of this being used on bridges.

The Province of New Brunswick has, since 1965, had a policy of using granite curbing in new bridge construction where sidewalks are a part of the structure. (Appendix "C"). Approximately 6,000 to 12,000 linear feet of granite curbing are used each year.

The Quebec Ministry of Transportation reports (Appendix "A") that granite is used only on main highways, especially roads subjected to salt and abrasion during winter months. The choice between granite, poured concrete, and prefabricated concrete curbing is determined by a complex formula that will be described in a later section. For a 3 year period (1979-1981), an average of 177,000 linear feet of granite curbing per year was installed, compared to 124,000 linear feet of poured concrete curbing and 70,000 linear feet of prefabricated concrete curbing. Thus almost 40% of the total curbing installed in the Province during this period was granite.

The Maine Department of Transportation reports (Appendix "D") that "practically all bridge curbing is granite." In 1982, 43,000 linear feet of granite highway curbing and edging was used. This either included, or was in addition to, 6,700 linear feet of bridge curbing on new construction.

The State of Vermont also uses granite for both bridge and roadway curbing. Their Transportation Agency reports (Appendix "E") that it has been used on 321 miles of interstate and other major bridges. Approximately 25% of their total bridge curbing has been granite. Approximately 1,100 linear feet are used annually. They also note that, for bridge curbing, "virtually no maintenance is required." "Roadway curbing is mainly used at the gutter line of sidewalks and may require resetting after a period of 20 years."

COSTS

Costs for granite curbing in the U.S. appears to be in the $14.00 to $18.00 (U.S.) per linear foot price range. In Northwestern Ontario, it has been estimated that split curbing could be produced at approximately $12.00 (Canadian) per linear foot and sawcut curbing at about $15.00 (Canadian) per linear foot.

Vermont notes that "installation costs of granite bridge curb is approximately $18.00 per linear foot more than a concrete bridge curb."

Except for data from Quebec (Appendix "A") few long term cost comparisons between granite and concrete were provided by the jurisdictions contacted. Vermont did note that, in 30 years of granite bridge curb use, they "have not replaced a granite bridge curb." They feel that the granite curbs "will outlast the concrete bridge deck." They also note that they have "replaced many concrete bridge curbs 40 to 50 years old with severe slab edge and concrete curb disintegration at cost several times the cost of granite curb."

As touched on earlier, Quebec has a procedure which allows the contractor to select the curbing material to be used according to a complex formula which takes into account long term maintenance and replacement costs as well as initial installation costs. (See Appendix "A") They estimate that all structural work on roads should last at least 36 years. Poured concrete curbing should last for at least 12 years and will normally have to be replaced at least twice in the 36 years. Thus, in order for poured concrete curbing to be used, it must be cheaper to install initially and to repair and replace twice during its life than it is to initially install granite which has a life of well over 36 years.

While little more specific hard data on long range cost/benefits were provided, all of the jurisdictions contacted seemed to be strongly of the opinion that, when looked at in the long term, significant cost efficiences were being realized by using granite curbing.

BENEFITS

The most obvious benefit to be derived from using local Ontario granite for bridge and highway curbing would be the long term savings to the Province resulting from greatly reduced maintenance and replacement costs. Although exact figures cannot be provided at this time, the potential savings outlined above appear to be significant.

The concrete curbing on many of the bridges of our highway system show unsightly signs of serious deterioration. In many instances not only is the concrete crumbling and falling in pieces onto the highway deck, but in some cases steel reinforcing rods are exposed - both these factors constituting safety hazards. The use of durable and attractive granite would thus offer benefits both in terms of improved safety and enhanced visual appearance of our highway system.

Finally, the use of granite on the Province's highway system would provide support for local Ontario industries, greatly assisting in the development and expansion of the Province's stone industry. It would result in increased production from the existing granite quarries, quite likely the development of additional new quarries, and most importantly, the installation of new fabricating plants to process the stone curbing. Once finishing plants are in place, this would, in turn, likely lead to additional quarrying and finishing of the Province's stone resources for other uses, such as building stone and monuments. All this would inevitably lead to additional new jobs and would result in other obvious economic benefits for the Province.

AVAILABILITY OF LOCAL GRANITE

At the present time there are at least three active granite quarrying operations in the Province, two in Northwestern Ontario and at least one in Eastern Ontario. There are also a number of other past or intermittently producing quarries that could be reopened on short notice. The granite produced or available from these quarries is of a quality equal to any produced for similar purposes in other jurisdictions. Quantities available are sufficient to meet the Province's curbing needs for many years.

There is not, at the present time, an established fabricating plant at any of the properties. Such a plant could however be set up on short notice once the market (i.e. government policy to purchase granite) is established. At least one present producer has already indicated an interest in doing so.

Even though there might not be an immediate source of Ontario stone, the first one or two contracts could be obtained relatively cheaply from producers in Quebec or Manitoba. Then, once the market in Ontario is established, local Ontario producers will quickly step forward to provide stone at competitive prices.

There is little question as to the availability of an assured supply of Ontario granite of proper quality once the market is established.

RECOMMENDATION

Based upon the above data, and the experience of other jurisdictions, it is recommended that the Province adopt a policy of using granite curbing in certain high maintenance situations. At the very least, a detailed cost/benefit study to determine the feasibility of switching to granite for certain curbing requirements should be undertaken. This could be followed by, or done concurrent with a test program using granite curbing on several bridge projects now under construction or being planned (preferrably in Northern Ontario). One suggestion would be several bridges on the Kenora bypass, now under construction.

It is further suggested that Ontario specifications call for a medium grained, pink granite that would be immediately available from the existing quarries.

It is also recommended that tenders be let in several annual 'calls' rather than one large one each year. This would make it possible for several of the local quarries to share the market each year.

APPENDIX 2

M.T.C. CORRESPONDENCE ON

GRANITE CURBING

memorandum

Ontario

To: B.J. Giroux, Manager
Estimating Office
Room 305, Central Building

Date: 83 12 19

FILE NO.: 3162-2-4-1

From: Soils and Aggregates Section
Engineering Materials Office
Room 311, Central Building

Re: COST OF CONCRETE CURB AND GUTTER IN NORTHERN ONTARIO

I am preparing a report on the use of granite curb as a replacement for concrete curb and gutter. Granite curb is available locally in Northwestern Ontario for $10.00 - 12.00 a foot. Granite is a strong (> 130 MPa) material, unaffected by the action of freezing and thawing. It may be installed as a substitute for concrete in a well compacted gravel. It is sufficiently durable that it may be re-used when the highway is re-constructed. When the overall cost of concrete curb is considered (placing, inspection, subsequent deterioration, and removal and replacement), granite may well be cheaper.

Will you please provide an analysis of the cost of concrete curb compared to granite curb for Northwestern Ontario. The following items or criteria are identified:

(a) Cost of removal of old curb

(b) Cost of installation by:

  (1) Amount of concrete required

  (2) Distance from Ready Mix Plant

(c) Estimated cost of installation of granite curb.

Your assistance in this matter would be greatly appreciated.

Chris Rogers

Chris Rogers,
Petrographer.

CAR/jlo

memorandum

Ontario

To: Mr. Chris Rogers,
Petrographer,
Soils and Aggregates Section,
Engineering Materials Office,
Room 311, Central Building.

Date: February 22, 1984.

From: Estimating and
Engineering Claims Office,
Room 305, Central Building.

RE: Cost of Concrete Curb vs. Granite Curb

Reference your memo to B.J. Giroux of 83-12-19 relative to the above subject.

We have reviewed empirical data to arrive at concrete curb and gutter costs. Going back to 1980, the weighted average price for concrete curb and gutter in Districts 18, 19 and 20 is $49.30/m. Individual contracts will, of course, vary due to concrete plant locations, availability of labour, etc.

Removal of existing curb and gutter in the above districts has a weighted average price of $4.65/m. This average includes one contract at $9.00/m which is unrealistic and a true average would probably be in the range of $4.00/m.

Similar to concrete curb and gutter, the cost for granite curb would vary with the distance the material must be hauled, available labour, accommodation costs, etc. We have estimated the cost of placing granite curb using your price of $12.00/L.F. and assuming an average haul of 150 miles to deliver the material. Allowing 5% prime contractor's mark-up, we estimate that the supply and installation would be $53.40/m.

I would point out that a comparison of costs is not entirely valid since the Ministry seldom uses plain curbing and practically all installations are curb and gutter. If we assume our standard curb section there would be a substantial savings in concrete compared to a curb and gutter section. By the same token, if curb and gutter and granite curb are placed in the same location relative to normal edge of pavement, the gutter portion substitutes for some portion of the granular base and hot mix pavement. We estimate this substitution to have a value of approx. $1.00/L.F.

As stated, there is very little use of a curb section on our contracts and the feasibility of substituting plain curb for curb and gutter in our design is not established.

If you have further questions or need clarification, contact the undersigned or Roy Hood at your convenience.

D.M. Hopper,
Assistant Manager,
Regional Operations.

DMH:cf

APPENDIX 3

RESUME OF A STUDY ON THE FEASIBILITY

OF GRANITE IN GOVERNMENT CONSTRUCTION

(QUEBEC)

ASSOCIATION DES PRODUCTEURS DE GRANITE DU QUÉBEC INC.

375, Verdun Street,
Quebec City, PQ
G1N 3N8
(418) 681-0071
(514) 286-7152

Resume Of A Study Prepared By The C.R.I.Q.*

*Centre de Recherches Industrielles du Québec

On The Feasibility Of Granite In Government Construction

BACKGROUND

The granite producers of Quebec have always been well aware of the economic value of building stone, and our industry has long been an important supplier of construction materials.

In recent years, however, we have lost share to competitive materials, such as terrazzo, ceramic tile, and concrete. Not because the intrinsic quality of stone has been in question, but because of a trend to materials which appeared cheaper and more flexible.

As a result, there was a risk, in the early 70's, that the entire industry might simply cease to exist.

Representations were made by the Quebec Association of Granite Producers, asserting the natural beauty of natural stone, the regional importance of its operations and the employment that the industry created. As a result of this, the Ministry of National Resources offered the Industry their help.

The basic idea was that the real economic value of the material in construction should be fully investigated. All professionals in the field were well aware of the legendary durability of granite, but none had yet measured accurately the relationship of this durability to the premium price.

The Ministry of Natural Resources decided, therefore, to commission experts to carry out a feasibility study on the use of granite in construction. If feasibility was demonstrated, the Ministry proposed to develop a utilization policy for the Government of Quebec.

After a call for tenders in March 1973, C.R.I.Q. was chosen to carry out this feasibility study. The text which follows is a resume of the document delivered to the Ministry of Natural Resources. Its conclusions were so clearly favourable to the use of granite that the Ministry of Public Works now specifies our material for curbing, for interior and exterior paving, and for treads in the buildings it constructs.

There is no doubt that the economic model developed by C.R.I.Q. for the Government of Quebec applies equally to private, public and institutional construction. That is why the Quebec Association of Granite Producers believes the report deserves study by all those engaged in the construction field.

This resume is merely a condensation of a report in 4 volumes and 600 pages. We have in our possession, and will release to anyone interested, the full text of the following documents:

1. Feasibility study on the use of granite as a construction material in Public Works projects. Volumes I, II and III. *C.R.I.Q. reference COM 79-0110 and COM 79-116 by Daniel Poisson and Jean-Paul Gagnon.*

2. Granite II (Technical study), final version, *C.R.I.Q. reference MO 5-0757, by Radu Kaufman, Eng.*

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1. Feasibility study on the use of granite as a construction material in Public Works projects. Volumes I, II and III. By Daniel Poisson and Jean-Paul Gagnon.

Volumes I and III contain the economic study itself, using two different models. Volume II contains the appendices, including the research methodology, the list of interviews, and a study by Hanscomb Roy Associates on the results of granite utilization on global construction costs of a number of public buildings. In the appendices are also a list of buildings visited, the "chart of maintenance time-allocations in the Ministry of Public Works", as well as all the FORTRAN programming of the feasibility model and the results obtained.

The objective of the economic study is to measure the cost — short, medium and long-term — of a range of materials. Included in these calculations are the factors of initial purchase price, installation costs, financing, repairs, maintenance and replacement.

Since these costs are spread over a period of time, they have been expressed in both current dollars (Vol. I) and in constant dollars (Vol. III). One is thus able to compare the economic performance of two given materials in the same application, and determine which is more economically feasible over the short, medium or long term.

The C.R.I.Q. study examines five materials: granite, poured concrete, precast concrete, terrazzo and ceramic tile, and compares each material in seven different applications: interior treads, exterior treads, interior flagging, exterior flagging, interior wall facing, exterior wall facing, and curbing. Below are two charts from Volumes I and III, grouping the comparative results, both as calculated in current dollars and in constant dollars. The conclusions reached by both models are in agreement and clearly demonstrate the economic viability of granite for interior treads, exterior treads, exterior flagging, interior flagging, and curbing.

Average Annual Unit Cost Over A period Of 50 Years (currant dollars)

Table I

	Granite	Poured Concrete	Precast Concrete	Terrazzo	Ceramic
Int. Treads (/lin. ft.)	12.60	12.60	(1)		
Ext. Treads (/lin. ft.)	2.05	3.60 (2) 5.00	(1)		
Int. Flagging (/sq. ft.)	14.50			16.00	13.80 (3) 14.50
Ext. Flagging (/sq. ft.)	1.25	2.45	1.25		
Int. Wall Facing (/sq. ft.)	1.60		0.85		0.60 (3) 0.95
Ext. Wall Facing (/sq. ft.)	2.00		1.40		
Curbing (/lin. ft.)	1.10	5.40	3.20		

(1) Insufficient quantitative data available for this application.

(2) $3.60 for treads cast on the ground and $5.00 for self-supporting treads.

(3) Upper figure, low-quality ceramic: lower figure, top-quality ceramic.

Average Annual Unit Cost Over A period Of 50 Years (constant dollars)

Table II

	Granite	Poured Concrete	Precast Concrete	Terrazzo	Ceramic
Int. Treads (/lin. ft.)	1.81	1.78		2.43	
Ext. Treads (/lin. ft.)	0.41	0.83			
Int. Flagging (/sq. ft.)	0.24	0.39	0.31		
Ext. Flagging (/sq. ft.)	2.00			2.12	1.97
Int. Wall Facing (/sq. ft.)	0.30		0.15		0.23
Ext. Wall Facing (/sq. ft.)	0.33		0.22		
Curbing (/lin. ft.)	0.21	0.84	0.48		

Methodology

The major task was the collection of data input for the mathematical model. To obtain the necessary data on the economic performance of the various materials, it was necessary to interview a considerable number of architects, builders, proprietors and administrators.

The Economic Model

The model aggregates all expenses incurred for a given material, taking into account the costs of initial purchase, installation, financing, repair, replacement and maintenance. Costs are calculated over 50 years, the generally accepted obsolescence period for a public building. As the various expenses are incurred at different points in time, it is possible to weight figures in order to express cumulative totals in constant dollars or in current dollars. Dollar comparisons can thus be made on an actualized basis or as viewed at the anticipated moment of expenditure (C.R.I.Q. Vol. I, page 137).

1. Initial purchase price. Costs were obtained from the manufacturers of the materials. For purposes of the study, costs were averaged.

2. Installation costs. These were obtained from the installers. The initial cost of a material could then be determined by adding purchase price, installation cost, cost to year 50, and financing cost. (In Vol. I the hypothesis is that the Government reimburses only the interest; in Vol. II a conventional type of financing is assumed, consisting of down payment and 50-year mortgage.)

3. Costs of repair, maintenance and replacement. For each material, the testimony of experts was used to establish the minimal program of repair and maintenance that would permit the material to reach a minimal life span. These life spans were determined by the experience of the experts and by the results of the technical study of the materials carried out by C.R.I.Q. (Granite II, Radu Kaufman, Eng.) All variables were calculated. Even the salvage value of a material which went past the 50-year durability limit was included. (A resume of life spans is shown in table III.)

4. Maintenance costs. Figures were obtained from the relevant experiences of major proprietors, as well as from the American Public Works Association.

Effective Life Spans Used In The C.R.I.Q. Study (normal conditions) (in years)

Table III

	Granite	Ceramic	Poured Concrete	Precast Concrete	Terrazzo
Exterior Flagging	100		10	20	
Interior Flagging	100	30			30
Exterior Treads	100		10	30	
Interior Treads	100		30	50**	30
Exterior Wall Facing	60			50	
Interior Wall Facing	100	30		50	
Curbing	60*		5	15	

* Under severe conditions

** Since cement is not salvageable, a more accurate time span is not necessary for purposes of determining residual market value.

Mathematical logic

As previously stated, C.R.I.Q. used two slightly varying approaches in its calculations of the costs inherent in each of the various materials. The desire for scientific accuracy led them to adopt the two approaches: one in current dollars, the other in constant dollars. It is interesting that, though the individual results vary appreciably from one model to the other, the same absolute tendencies hold true, giving credibility to whichever model is chosen.

The model in Vol. I, in current dollars, expresses the cost of materials in a curve plotting total cumulative costs. In this way one obtains the cumulated costs incurred over a period of years, and the gradient of the curve reflects the average annual unit cost of the material (See Fig. I)

For example, the VTC curve for granite curbing compounds the cost of purchase and the cost of financing, which is translated by a straight line. The curve for precast concrete, however, follows a stairway patterns, where each flat landing indicates the replacement of the curbing.

By taking the average gradient of the curves, a good indication of the unit cost of the material is obtained, as this is demonstrated in Fig. I.

The model used in Vol. III is more sophisticated, because it makes allowance for the time factor contained in the expenses incurred for each material. We are all well aware that a dollar spent in ten years time has a very different value from a dollar spent today, both in purchasing power and in intrinsic value.

This second model also calculates financing costs, but by a method much more responsive to the conditions normally encountered by the private promoter, in terms of investment, repayment and cost of opportunity.

Once again the results are expressed in a curve which compounds cumulative unit costs — in constant dollars, this time — for each material. The gradient of each curve indicates the actualized unit cost, as can be seen in Fig. I, which shows this type of curve as it applies to exterior flagging.

2. Technical Study
Granite II, File C.R.I.Q. MO 5-0757

by Radu Kaufman, Eng.

This study is the technical yard-stick in the feasibility study of granite used in government construction. It represents many hours of laboratory procedures and visits to construction sites over a period of years.

The objective of all this research was to determine the average life span of the materials used, in the different applications covered by the study. The life spans, shown in Table III, were obtained through laboratory tests on resistance to freezing, to acids, to pressure, etc . . . and also from the practical experience of proprietors and administrators of public buildings.

This part of the study, in fact, provided the major basis for calculation of the viability of the materials examined, and C.R.I.Q. handled it with appropriate thoroughness. Bibliography also played an important role.

Conclusion

We believe that it is the first time a model has been developed to measure and compare the time-weighted importance of various materials.

Two years of research were necessary before C.R.I.Q. could reach these conclusions.

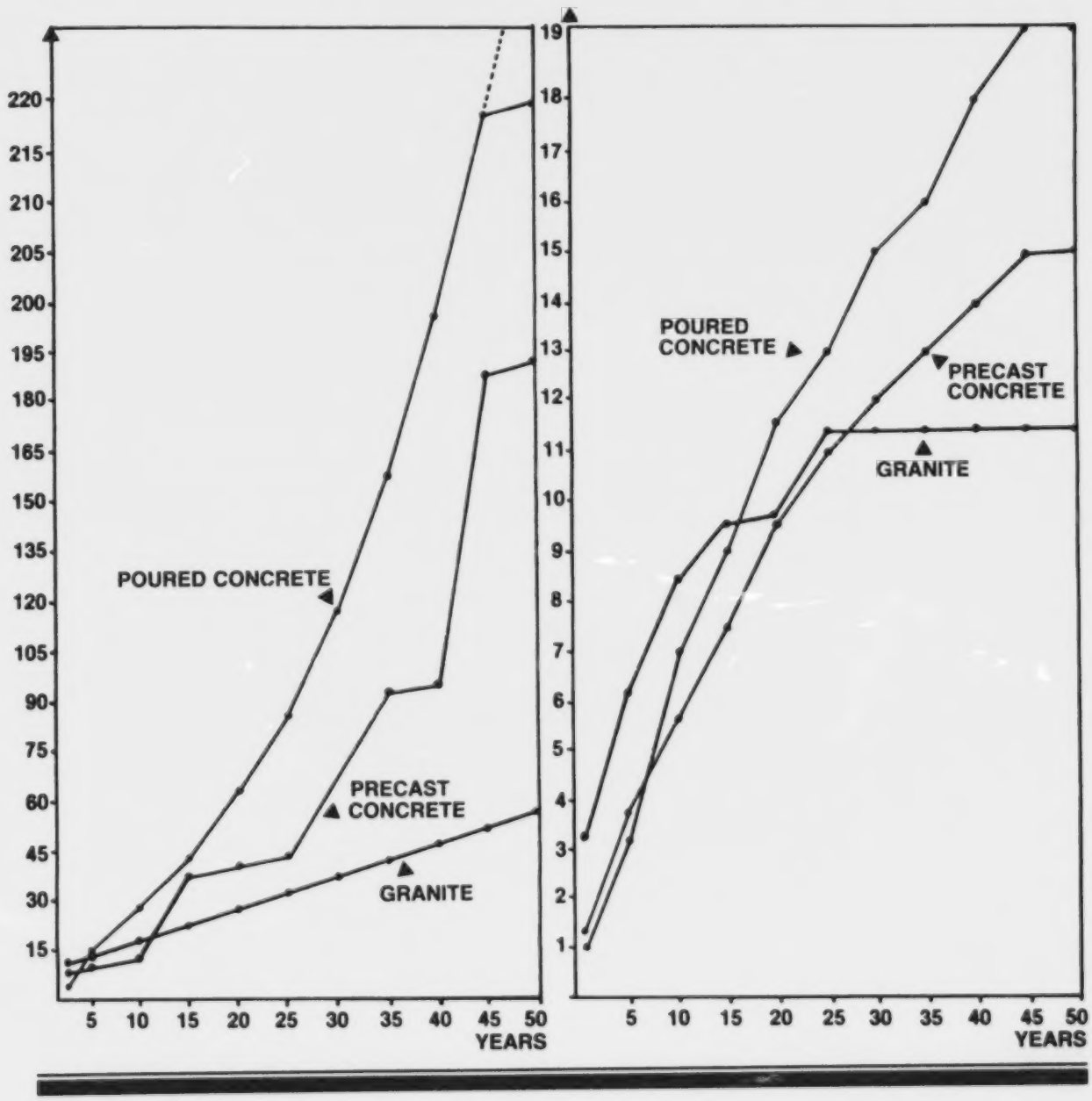
It is clear that this scientific study confirms the feelings of many construction experts: that granite is economically viable in the severe conditions encountered in public buildings, for both interior and exterior use.

In addition, a subsequent study, carried out by C.R.I.Q. on behalf of the Quebec Association of Granite Producers, may well forecast the ***economic viability of granite*** *as a wall facing, too. Technological advances, already being achieved by producers, will reduce purchase and installation costs for granite wall facings, bringing their average cost to a level below that of other competitive materials.*

The Quebec Association of Granite Producers wishes to thank the Department of Natural Resources and C.R.I.Q. for their professional collaboration. The study which they developed, and which we are now able to offer to architects, engineers and proprietors, is an advanced decision-making tool. Today granite is not only a material with high aesthetic appeal, but also, demonstrably, an excellent investment.

FIGURE 1
CURVES OF CUMULATIVE UNIT EXPENDITURES FOR STREET CURBINGS
VOLUME 1 PAGE 162

FIGURE 2
CURVES OF UNIT EXPENDITURES (IN CONSTANT DOLLARS) FOR EXTERIOR FLAGGING
VOLUME 2 PAGE 20



APPENDIX 4

SPECIFICATIONS RELATED TO USE OF GRANITE

CURBING IN HIGHWAY CONSTRUCTION

ASTM C615-68

New York State Thruway Authority

New Hampshire Dept. of Public Works and Hwys.

New Brunswick Dept. of Transportation

Maine Dept. of Transportation

Vermont Agency of Transportation

Quebec Ministry of Transportation

U.S. Dept. of Transportation

Massachusetts Dept. of Public Works

Connecticut Dept. of Transportation

AMERICAN NATIONAL STANDARD ANSI/ASTM C 615 - 68 (Reapproved 1977)

Standard Specification for STRUCTURAL GRANITE[1]

This Standard is issued under the fixed designation C 615; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval.

1. Scope

1.1 This specification covers the selection, sampling, and testing of commercial granite for building and structural uses.

1.2 Structural granite shall include all varieties of commercial granite[2] that are sawed, cut, split, or otherwise shaped for building purposes. It shall specifically exclude (*1*) sculpture, (*2*) molded, cast, or otherwise aggregated units composed of fragments, and (*3*) crushed or broken granite.

2. Classification

2.1 Structural granite shall be classified according to use into two major categories and additional subcategories as follows:

I *Engineering Grade:*
- Bridge piers, sea and river walls, dams, and related structures,
- Bridge superstructures, grade separations, and retaining walls,
- Flexural members, and
- Curbstone and pavements.

II *Architectural Grade:*
- Monumental structures,
- Institutional buildings,
- Commercial buildings,
- Residential buildings, and
- Landscaping, parks, and other ornamental and private improvements.

3. Physical Requirements

3.1 Structural granite supplied under this specification shall conform to the physical requirements prescribed in Table 1.

3.2 Structural granite shall be sound, durable, and free from imperfections such as starts, cracks, and seams that would impair its structural integrity.

3.3 Granite supplied under this specification shall be free from minerals that will cause objectionable staining under normal environments of use.

3.4 The desired color and the permissible natural variations in color and texture shall be specified by carefully detailed description or by naming granites having the required characteristics.

4. Sampling

4.1 Samples, if required for inspection, comparison, or physical testing, shall be submitted in duplicate and shall be certified by the producer as representative of the granite to be used.

---

[1] This specification is under the jurisdiction of ASTM Committee C-18 on Natural Building Stones.
Approved Sept. 13, 1968.

[2] See ASTM Definitions C 119, Terms Relating to Natural Building Stones, which appear in the *Annual Book of ASTM Standards*, Part 19.

TABLE 1 Physical Requirements

Physical Property	Test Requirements	ASTM Test Method[a]
Absorption by weight, max, percent	0.4	C 97
Density, min, lb/ft³ (kg/m³)	160(2560)	C 97
Compressive strength, min, psi (MPa)	19 000(131)	C 170
Modulus of rupture, min, psi (MPa)	1 500(10.34)	C 99

[a] These designations refer to the following test methods:
C 97, Tests for Absorption and Bulk Specific Gravity of Natural Building Stone.[3]
C 99, Test for Modulus of Rupture of Natural Building Stone.[3]
C 170, Test for Compressive Strength of Natural Building Stone.[3]

---

[3] *Annual Book of ASTM Standards*, Part 19.

The American Society for Testing and Materials takes no position respecting the validity of any patent rights asserted in connection with any item mentioned in this standard. Users of this standard are expressly advised that determination of the validity of any such patent rights, and the risk of infringement of such rights, is entirely their own responsibility.

This standard is subject to revision at any time by the responsible technical committee and must be reviewed every five years and if not revised, either reapproved or withdrawn. Your comments are invited either for revision of this standard or for additional standards and should be addressed to ASTM Headquarters. Your comments will receive careful consideration at a meeting of the responsible technical committee, which you may attend. If you feel that your comments have not received a fair hearing you should make your views known to the ASTM Committee on Standards, 1916 Race St., Philadelphia, Pa. 19103, which will schedule a further hearing regarding your comments. Failing satisfaction there, you may appeal to the ASTM Board of Directors.

GERALD CUMMINS
CHAIRMAN

EDWIN J. FEHRENBACH
VICE CHAIRMAN

CHARLES T. LANIGAN
TREASURER

PHILLIP B. LEE
EXECUTIVE DIRECTOR

NEW YORK STATE THRUWAY AUTHORITY

200 SOUTHERN BOULEVARD
POST OFFICE BOX 189
ALBANY, NEW YORK 12201

DEPARTMENT OF ENGINEERING
AND MAINTENANCE

JOHN P. PENDLETON
CHIEF ENGINEER

BUREAU OF
THRUWAY MAINTENANCE

THOMAS M. CLEARY
SUPERINTENDENT

PHONE (518) 449-1750

October 19, 1976

Mr. Chris Rogers
Aggregate Evaluation Engineer
Province of Ontario
Ministry of Transportation & Communications
Engineering Services Branch
Laboratory Services Office
1201 Wilson Avenue
Downsview, Ontario M3M 1J8
Canada

Dear Mr. Rogers:

In response to your 6 October 1976 letter to Chairman Gerald Cummins concerning granite curbing for bridge decks, we have enclosed our purchase specifications, bidders list, and standard sheets detailing installation. This material is self-explanatory.

The granite quality is controlled mainly by geological examination of the quarry and a stone hardness test. However, physical examination of the curbing on delivery for weak or soft seams and workmanship is also important. Tapping questionable areas with a hammer is often a productive inspection measure. Material cost is about $5/foot, or $12-15/foot installed on the bridge by a contractor.

Granite curbing is also used in our service areas. There it is bedded in sand and asphalt concrete paving is placed to the curb face. It is both salt proof and resists snow plow damage.

In summary we have been quite happy with the performance of our granite curbing. It is very durable and can be dismounted and reset when a bridge is repaired or rebuilt.

Please feel free to contact us should you have any further questions.

Very truly yours,

JOHN P. PENDLETON
Chief Engineer

JPP:III:da

TA-3225 (10/69)

BIDDERS LIST

NEW YORK STATE THRUWAY AUTHORITY

PROPOSAL OR QUOTATION NUMBER	GROUP NUMBER	DATE OF OPENING
[illegible]	31	April 28, 1976

DESCRIPTION	PREPARED BY
Granite Curbing	

TOTAL NUMBER OF BIDDERS

From cards _____ + other _____ = TOTAL _____

1 [illegible] Granite Co., Inc. [illegible]	9 [illegible] Corp. P.O. Box 402 Barre, Vermont 05641
2 [illegible] Granite Corp. [illegible]	10 Bonazzi and Son Montpelier, Vermont 05602
3 [illegible] Co., [illegible] Charleston, WV [illegible]	11 [illegible], Stains Fetch, Inc. Barre, Vermont 05641
4 [illegible] Granite Corp. [illegible]	12 Jones Brothers Co., Inc. Barre, Vermont 05641
5 Barre Building Granite Co. Barre, Vermont 05641	13 Parker Green Granite Co. ~~Barre, Vt.~~ ~~St. Peters, Pa. 19470~~ PO Box 294 Lafayette Hill, Pa 19444
6 [illegible] Granite Co. [illegible]	14 [illegible] Granite Corp. [illegible]
7 International Granite and Marble Corp. 240 Main Street [illegible]	15 [illegible] Granite Quarries [illegible]
8 ~~[illegible] Granite Co.~~ Mail with ~~Main Street~~ [illegible]	16 Georgia Granite Co. [illegible]

TA-3225 (10/69)

BIDDERS LIST

NEW YORK STATE THRUWAY AUTHORITY

PROPOSAL OR QUOTATION NUMBER	GROUP NUMBER	DATE OF OPENING
1194	313	April 20, 1970

DESCRIPTION	PREPARED BY
Granite Curbing	

TOTAL NUMBER OF BIDDERS

From cards _____ + other _____ = TOTAL _____

1 Georgia Granite Co. Route 1 Box 55 Nelson, Ga 30693	9
2 D. Rumble & Sons 167 Main Street Tuckahoe, NY 10707	10
3 Robert Stone Dealers 759 Columbus Road Saugerties, NY 12477	11
4 Massabesic Stone Co. Box 273 East Otis, Ma 01029	12
5 ~~Daily Government Advertiser 300 West 43rd Street New York, New York 10036 Attn: Ed Howard~~	13
6	14
7	15
8	16

NEW YORK STATE THRUWAY AUTHORITY
200 Southern Boulevard
Albany, New York 12209

Mailing Address: P.O. Box 189
Albany, NY 12201

GROUP NO: 318
SPECIFICATION NO: 15671-5 (5/74)
& Drawing (1)
ISSUED: April 14, 1976

GRANITE CURBING
(This specification consists of 4 pages.)

Bidders are requested to retain this specification for future reference in connection with the items listed herein.

GENERAL INFORMATION

Any questions concerning this specification and proposal should be directed to Paul R. Young, Director of Purchasing.

GENERAL SPECIFICATION CHANGE:

Bids submitted shall remain in effect past the period reserved in the General Specifications for making an award unless and until either the bidder in writing withdraws his bid or a contract is awarded, whichever is first.

QUANTITY: As called for in the Proposal.

PRICE:

Price shall be net and shall include transportation, delivery and unloading charges fully prepaid by the contractor, f.o.b. point,of delivery indicated in the proposal.

CONTRACT PERIOD: Prompt Delivery.

METHOD OF AWARD: Award will be made by total bid.

INFORMATION TO BE FURNISHED WITH BID:

If the curbing offered differs from the provisions contained in this specification, such differences must be explained in detail. Bid will receive careful consideration if such deviations do not depart from the intent of this specification and are to the best interests of the using department, as interpreted by the Director of Purchasing.

QUALIFICATION OF BIDDER:

No bid will be considered unless the firm submitting the bid can meet the following condition:

1. That it has in operation a quarry adequate for furnishing the granite curbing.

GENERAL INFORMATION (Cont'd)

QUALIFICATION OF BIDDER: (cont'd)

NOTE: On a bid from a distributor, a certificate executed by the manufacturer may be required stating that the said bidder is authorized to supply his merchandise and that all the qualifications and all the requirements of the specification and the proposal are complied with.

SAMPLE:

Bidder MUST furnish with his bid an approximately 3" x 6" x 1" sample of granite which he proposes to furnish.

DETAILED SPECIFICATIONS

ITEM 1: - GRANITE CURBING TYPE A

Granite curbing described herein will be furnished in accordance with Thruway Authority Drawing No. 8-5-2-AT (Rev. 2/23/76), attached, which is hereby made a part of this specification.

The stone curb shall be of a hard and durable granite of a color satisfactory to the Authority, free from seams which impair its structural integrity and of a good smooth appearance. The granite shall come from approved quarries and when tested, shall have a "Dorry Hardness Value" of not less than seventeen.

There shall be no depression on the back surface which would exceed a batter of 1/2 inch horizontal on 3 inch vertical.

The front exposed face shall be at right angles to the plane of the top and shall be smooth quarry split, free from drill holes in the exposed surface.

There shall be no projection greater than 3/4 of an inch or depression greater than 1/2 inch measured from the plane of the face through the front arris lines for a distance of 8 inches down from the top. For the remaining distance there shall be no projection or depression greater than 1 inch measured in the same manner. The arris lines at the ends shall be pitched with no variation from the plane of the face greater than 1/8 inch.

The ends of all curb sections shall be square with the planes of the top, back and face, and so finished that when the sections are placed end to end as closely as possible, no space more than 1/2 inch shall show in the joint for the full width of the top surface and down on the face 8 inches. The remainder of the end may break back not over 6 inches from the plane of the joint.

The curb shall be thoroughly cleaned and free from any iron rust or iron particles.

7540-1318 (10/78)

GRANITE CURBING

GROUP NO: 318
SPECIFICATION NO: 15671-5 & Drawing (1)
ISSUED: April 14, 1976

DETAILED SPECIFICATIONS (Cont'd)

ITEM 2: GRANITE CURBING - TYPE B:

Granite curbing described herein will be furnished in accordance with Thruway Authority Drawing No. 8-5-2-AT (Rev. 2/23/76, attached, which is hereby made a part of this specification.

The stone curb shall be of a hard and durable granite of a color satisfactory to the Authority, free from seams which impair its structural integrity and of a good smooth appearance. The granite shall come from approved quarries and when tested, shall have a "Dorry Hardness Value" of not less than seventeen.

There shall be no depression on the back surface which would exceed a batter of 1/2 inch horizontal on 3 inch vertical.

The front exposed face shall be at right angles to the plane of the top and shall be smooth quarry split, free from drill holes in the exposed surface.

There shall be no projection greater than 3/4 inch or depression greater than 1/2 inch measured from the plane of the face through the front arris lines from top to bottom. The arris lines at the ends shall be pitched with no variation from the plane of the face greater than 1/8 inch.

The ends of all curb sections shall be square with the planes of the top, back and face, and so finished that when the sections are placed end to end as closely as possible, no space more than 1/2 inch shall show in the joint for the full width of the top surface and down on the face for the full depth.

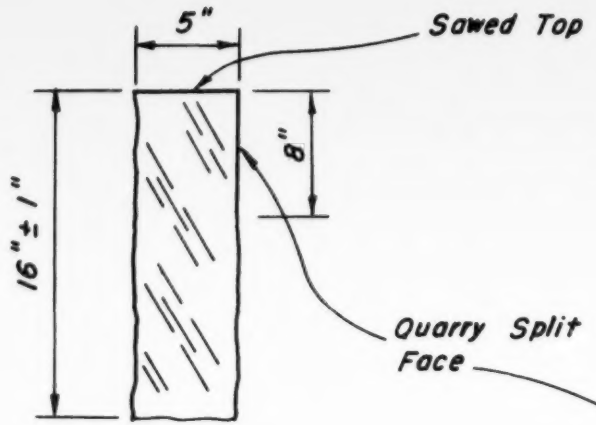
The curb shall be thoroughly cleaned and free from any iron rust or iron particles.

All straight sections shall be furnished in lengths of not less than three feet nor more than six feet long. Length to be marked on each piece.

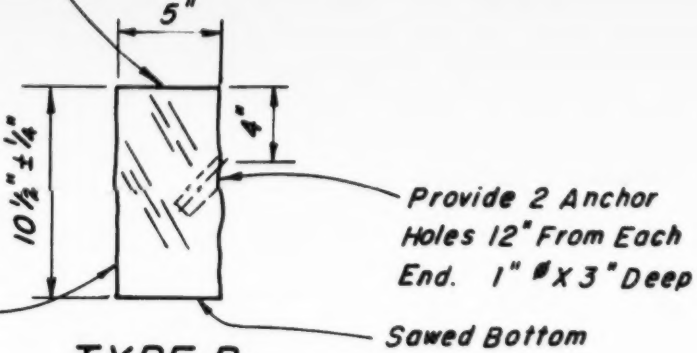
Anchor holes shall be provided as shown.

SHIPPING:

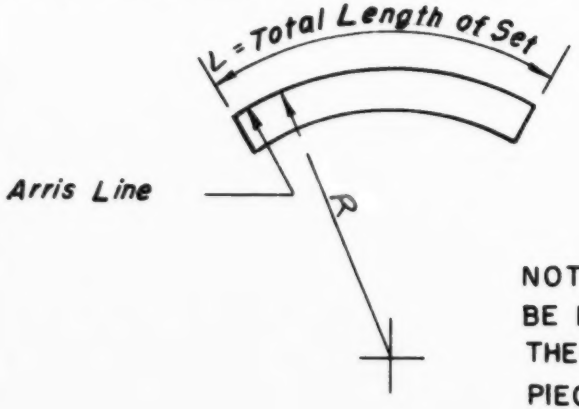
Shipping and unloading of granite curb must be done in a manner to insure against chipping or cracking. The contractor shall advise the Division Engineer, in advance of the date and approximate time each shipment will arrive at the destination. This will enable the Division Engineer to prepare the site for reception of shipment.



TYPE A
GRANITE CURB
Random Length - Straight
Twy. Part No. 35-02-05-57



TYPE B
GRANITE CURB
(BRIDGES)



	90° Sets	
TWY. Part No.	R	L
35-02-05-60	5'	7'-10"
35-02-05-61	10'	15'-8"
35-02-05-62	15'	23'-6½"
35-02-05-63	20'	31'-5"

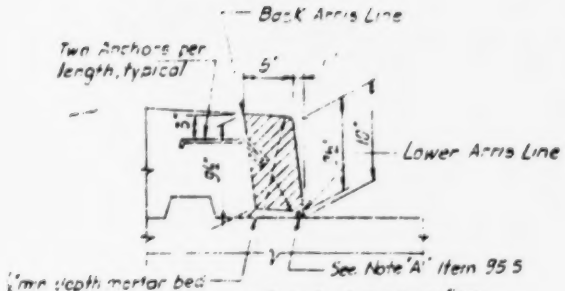
NOTE: THESE ITEMS TO BE FURNISHED IN SETS WITH THE MINIMUM LENGTH OF A PIECE TO BE CONSISTANT WITH INDUSTRY PRACTICE.

REVISED 2-23-76

NEW YORK STATE THRUWAY AUTHORITY
Department of Engineering and Maintenance

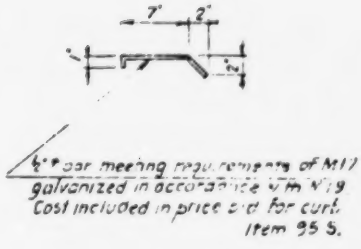
GRANITE CURB

Drawn by RK | Date 3-12-65
Checked by HB | Dwg. No. 8-5-2-AT



Note: Score top of safety curb at each Granite Curb Joint Location

GRANITE CURB
Scale: 1½"=1'-0"



¾" bar meeting requirements of M17 galvanized in accordance with M19 Cost included in price bid for curb Item 95 5.

ANCHOR BAR
Scale: 1½"=1'-0"

REHABILITATING EXISTING BRIDGE
AT MILEPOST 337.47
DECK DETAILS
NEW YORK STATE THRUWAY AUTHORITY

TAS 75-103

Note "A"
Rake out joint to a depth of ½" and min. point flush with epoxy mortar consisting of 3 parts of mortar sand to one part of M29A Epoxy Polysulfide binder by volume, cost to be included in price bid for Item 95 5.

Appendix "B"

STATE OF NEW HAMPSHIRE

DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS

JOHN O. MORTON BUILDING
CONCORD, N.H. 03301

JOHN A. CLEMENTS, P.E.
COMMISSIONER

MINISTRY OF NATURAL RESOURCES
RECEIVED
AUG 23 1982

August 17, 1982

R. [illegible] OF KENORA

P.O. Box 5160
Kenora, Ontario
P9N 3X9

Dear Mr. Beard:

This letter is in response to your request, dated July 7, 1982, for information concerning the uses of natural stone in highway construction. In New Hampshire natural stone is used primarily as an aggregate base course material and for stone curbing. Occasionally stone is used as an ornamental facing on bridge abutments and on retaining wall structures.

Generally, stone curbing is employed on bridges, in the construction of interchanges and along urban routes. The stone curbing is made from light grey, medium to fine grained granite which is supplied from two quarry sources in New Hampshrie.

Enclosed is a copy of our Standard Specifications, a Standard Plan Sheet, information on the total volumes used during a 12 month period (4th quarter 1980; 1st, 2nd and 3rd quarters 1981) and the average bid prices for those items.

The maintenance for granite curbing is negligible. The granite curbing is nearly indestructible and can be salvaged for reuse.

I hope that the attached information will be of some help.

Yours truly,

Richard M. Lane
Research Geologist

RML/ln
Enclosures

Materials & Research Division
P.O. Box 483/Stickney Avenue
Concord, New Hampshire 03301
Tel: (603) 271-3151

grade. A string line may be used as a guide to maintain alignment and to eliminate minor variations in the grade of the post tops as the posts are being set in their final position. A carpenter's level may be used to assure that posts are vertical. Concrete used for post bases should be poured slightly above the surrounding ground and rounded on top to drain water. Wire and fabric should be taut and spaced as shown on the plans with the specified clearance under the fabric to prevent children and small animals from crawling under the fence.

D. Measurement. The plans and specifications should be consulted for the proper limits of measurements. In the case of resetting railing or fencing, a measurement should be taken prior to initial removal to account for possible lost or damaged material at a later date.

SECTION 608 - SIDEWALKS

608.3 - CONSTRUCTION OPERATIONS.

The location and grade of a sidewalk is usually dictated by the curb line. Sidewalk locations and grades, especially those not adjacent to curbs, should be staked and checked well in advance of the work.

The engineer should review the roadway typical section sheets of the plans to know the design and slope of the sidewalk, particularly in the vicinity of an approach or driveway. Once the sidewalk is constructed, he should be concerned with the development of the area behind the walk in regard to matching residential lawns, walks and steps in a practical and aesthetic manner.

Special attention must be given to the timing of all utility structure alterations within or beneath the sidewalk so that this work is completed well in advance of the sidewalk construction.

SECTION 609 - CURB

609.1 - GENERAL.

A recent change in slope curb introduces an item of radial joint granite slope curb to provide for curb cut on radial joints with radii of 2 through 15 feet. Curb with 1.5 foot radius or less will continue to be curved granite slope curb and over 15 foot radius will be considered straight granite slope curb even though it may be necessary to field cut joints to fit a radius.

609.2 - MATERIALS.

The specifications are complete as to material requirements and also include a useful chart showing required finished surfaces and allowable tolerances for checking granite curb.

610

609.3 - CONSTRUCTION OPERATIONS.

Location should be staked and checked well in advance of the work. Proposed locations of driveways and drainage structures should be reviewed. The contractor should set a line at the front top of the curb and have the engineer review it far ahead of any curb setting. Before any set curb is mortared the line and grade should be sighted and approved by the engineer. Where a sudden change in pavement crown is encountered - as where a roadway slope of ¼"/ft. meets a bridge slope of 1/8"/ft. - care must be taken tc obtain a transition that will eliminate drainage problems without drastically changing the curb reveal and still give a pleasing grade to the curb and related guardrail. Setting a string line on stakes and sighting the line is a good method to lay out and check such transitions. All curb will be set on a thoroughly compacted base. Overexcavation without proper backfill and compaction before setting curb will not be allowed. This is especially important adjacent to structures.

When an island bounded by curb is to be surfaced with concrete, curb joints should be located at construction joints to allow for shrinkage cracking in the concrete. The curb joints should coincide with the construction joints or the curb is likely to crack beside the construction joints.

Bridge curb is normally adjusted to line and grade by a system of wedges - a pair on the front and back near each end of each curb. The line and grade must be checked and approved before any mortaring is done. After approval the bottom of the curb at each end is mortared and allowed to set so the wedges may be removed, then the balance of the bottom of the curb is mortared.

Great care must be taken to insure that all wooden wedges and parts thereof are removed and that the area under the curb is completely filled with mortar. The most acceptable method of mortaring curb is to drive all mortar under the curb from the face side until it reaches the back, rather than place martar from both sides. Any void or wooden wedge will later become filled with water and is almost certain to freeze and loosen the curb.

Bituminous curb must be laid on a smooth firm surface, usually hot top or surface treatment, to provide a base for the curb and smooth area for the curb machine. Any rough or poorly graded area under the curb machine will be reflected and magnified in the line and grade of the curb.

SECTION 610 - BITUMINOUS GUTTER AND SLUICE

610.1 - GENERAL.

This item is generally used as a means to control erosion where the type of soil and the grade are such that the quantity of water flowing would cause serious erosion if the gutter or sluice were not paved.

SECTION 609 — CURBS

Description

1.1 This work shall consist of constructing or resetting curbing as shown on the plans or as ordered.

Materials

2.1 General. Curb shall be constructed of new granite curbing, salvaged granite curbing, cement concrete, or bituminous concrete, as indicated in the proposal.

2.2 Granite shall be hard, durable, reasonably uniform in appearance, and free from weakening seams; solid quartz or feldspar veins wil not be cause for rejection.

2.2.1 Surfaces of each stone shall be finished in accordance with the requirements of Table 1. All comparable curbs on the project shall have similar finish.

2.2.2 When the slope curb item description does not indicate a specific height, the size of the stone shall be that as shown on the standard entitled "Granite Slope Curb." The setting reveal (the vertical height of the exposed face when set) shall be 4 inches or as shown on the plans.

2.3 Salvaged Granite Curbing shall, if necessary, be dressed to obtain joints of the same width as specified for new curb.

2.4 Cast-in-Place Concrete Curbing. (See 2.5).

2.5 Precast Concrete Curbing. When a quantity for 2.4 or 2.5 is included in the proposal, specifications governing the materials and construction requirements will be provided in the special provisions.

2.6 Bituminous Concrete shall meet the requirements of 401. The mixture shall be designed to extrude properly with a uniform, smooth appearance.

Table 1 — Finished Surfaces and Tolerances for Granite Curbing

Type	Area	Finished Surface	Tolerance, in.	
A	Top	5" wide or as otherwise shown, sawn true plane —	+1/8	−1/8
		Front and back arris lines pitched straight and parallel —	+1/8	−1/8
	Front face	Right angle to top, approximately true plane —	+1	−1/2
		No drill holes showing in top 10".		
	Back face: Exposed	Plane parallel with front face.		
		Straight split to 1-1/2" below exposed surface —	+1	−1
		No larger than 1/4 inch segment of drill holes showing in arris lines.		
	Concealed	Below 1-1/2" from exposed surface —	+1-1/2	−1-1/2
	Bottom	Approximately parallel to top.	See plans	
		Minimum width: 8 inches.		
	Ends: Exposed portion	Square with planes of top and face.		
	Joints: Exposed	Optimum width: 1 inch.		
	Concealed	To break back no more than 4 inches.	+3/4	−3/4
	Lengths of stones	Three feet to 10 feet or as indicated.		
Bridge	General	To conform to Curb A except as specified below.		
	Exposed surfaces	No drill holes showing; none in back face arris lines.		
	Bottom	Width equal to width of top —	+1	−1
	Joints: Exposed	Maximum width: 1/2 inch.	+1/4	
	Concealed	To break back no more than 1 inch.		
Inlet	Surface	To conform to that of Curb A or to other curb to which it is adjacent.		
		Opening shall be bush hammered or flame finished, to a reasonably smooth finish.		

Type	Area	Finished Surface	Tolerance, in. [a]	
	Arris lines	Straight and true on top, front and ends. Drill holes not deeper than 1/4" inch allowed in arris lines.	+1/4	-1/4
	Faces Exposed part	Planes; no drill holes in faces longer than 3" or deeper than 1/4"		
	Concealed part	Drill holes not objectionable.	+1	-1
Slope and End Stone	Ends	Square with face except as indicated.		
	Joints	On tangent, maximum width: 1 inch.	+1/2	-1/2
		On curves over 15 ft. radius, widen top or bottom from 1" as necessary.		
		On curves with 15 ft. radius and under, use radial joints or curved curb as indicated.		
		Optimum width: 1 inch	+1/2	-1/2
	Length of stones	Min. and max. specified lengths —	See plans.	

[a] +Projection in stone; -Depression in stone.

2.6.1 Asbestos fiber meeting Canadian Quebec Miner Specification Grade 7M shall be uniformly incorporated in the dry mix in the proportion of approximately 2-1/2 per cent of the total batch weight.

2.6.2 Acrylic emulsion curb paint shall conform to 708-NH 4.31.

2.6.3 Beads for reflectorization shall conform to 708-NH 4.13.

2.7 Cement Mortar shall conform to 569 except that cement mortar for bedding curb (bridge) shall be an approved mortar consisting of sand, cement, and a factory-proportioned blend of metallic aggregate, water-reducing agent, plasticizing agent, and accelerating agent, which materials when mixed with water at the rate recommended by the manufacturer will produce a non-shrinking grout.

2.7.1 Metallic aggregate consisting of predominately iron produces a brownish colored mortar. Metallic aggregate consisting of predominately aluminum produces a light color.

2.8 Curb Anchors shall be steel of the shapes and dimensions shown on the plans.

Construction Requirements

3.1 Granite Curb, New and Reset.

3.1.1 Curbing to be salvaged and reset shall be carefully removed and stored. The Contractor shall replace any curbing damaged or lost because of his negligence.

3.1.2 Excavation for curb shall be made to the required depth, and the base upon which the curb is to be set shall be compacted to a firm, even surface.

3.1.3 Installation of curbing shall be so that the front top arris line conforms to the line and grade required. All spaces under the curbing shall be filled with material conforming to the requirements for roadway base course. This material shall be thoroughly tamped.

3.1.4 Joints shall be of the width indicated in Table 1. They shall be pointed with mortar and the exposed portions finished with a jointer.

3.1.5 All exposed portions of reset curbing shall be cleaned by sand blasting.

3.1.6 Backfilling shall be of approved material, placed and thoroughly tamped in layers not exceeding 6 inches in depth.

3.1.7 Curb (Bridge) shall be set on a mortar bed of non-shrink mortar. The use of brownish mortar is restricted to areas which are not exposed to view in the completed work. The front face shall be plumb and the top shall conform to the required line and grade. All joints shall be grouted and the exposed portions finished with a jointer. Long and short

lengths of curb shall be laid alternately unless otherwise ordered.

3.1.7.1 Curb anchors shall be set and grouted as shown on the plans.

3.1.8 Granite curb inlets shall be set in full mortar beds and shall conform to the required line and grade.

3.2 Bituminous Concrete Curb.

3.2.1 Prior to placing the curbing, the surface of the pavement shall be cleaned as directed and painted with a tack coat of bituminous material when ordered.

3.2.2 The curbing shall be placed by means of an approved extruding curb-paver. The curbing shall be compacted to a minimum density of 90 per cent of a laboratory-compacted sample of the same mix. A tight bond shall be obtained between the prepared course and the curb and between necessary curb joints.

3.2.3 Unless unpainted curb is specified, after a curing period which shall be as long as project conditions permit, but not less than 7 days, exposed surfaces of the curbing shall be sprayed with 2 coats of acrylic emulsion curb paint.

3.2.4 The beads for reflectorization shall be applied by the drop-on method at the time of application of the second coat of paint, evenly and uniformly, at the rate to obtain the adhesion of the maximum number of beads possible. Dead spots, found upon testing after dark, when ordered, shall be repainted and additional beads applied.

Method of Measurement

4.1 Curb will be measured by the linear foot to the nearest 0.1 of a foot from end to end along the lower edge of the exposed face of the curbing. Only curbing actually cut to a radius will be considered as curved curb.

4.2 Granite curb inlets will be measured by the number of units installed.

Basis of Payment

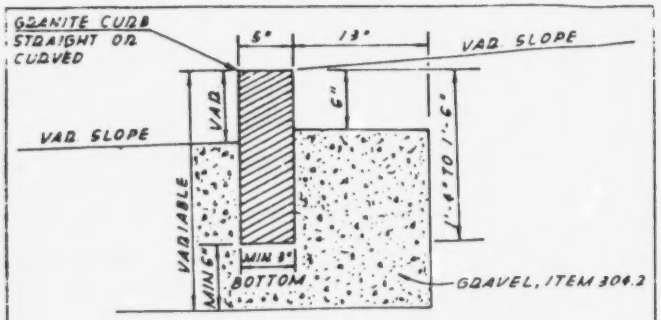
5.1 The accepted quantities of curb will be paid for at the contract unit price per linear foot for each type of curbing specified complete in place, except that all special cutting ordered due to changes in the plans will be paid for as extra work.

5.2 The accepted quantities of granite curb inlets will be paid for at the contract unit price per each complete in place.

5.3 Roadway base course material adjacent to the curb will be paid for under the appropriate items and no deduction will be made for the volume occupied by the curb. In the process of setting the curb, excavation and backfill of the material that has been placed by the Contractor will be considered as incidental to the item.

Pay items and units:

609.01	Straight Granite Curb A	Linear Foot
609.02	Curved Granite Curb A	Linear Foot
609.21	Straight Granite Slope Curb	Linear Foot
609.22	Straight Granite Slope Curb with Radial Joints	Linear Foot
609.23	Curved Granite Slope Curb	Linear Foot
609.3	Straight Granite Curb (Bridge)	Linear Foot
609.41	Granite Curb Inlets A	Each
609.42	Granite Curb Inlets B	Each
609.5	Reset Granite Curb	Linear Foot
609.6	Straight Precast Concrete Curb	Linear Foot
609.61	Curved Precast Concrete Curb	Linear Foot
609.7	Vertical Concrete Curb, Cast-in-Place	Linear Foot
609.76	Concrete Slope Curb, Cast-in-Place	Linear Foot
609.8	Bituminous Concrete Curb	Linear Foot
609.81	Bituminous Concrete Curb, Unpainted	Linear Foot

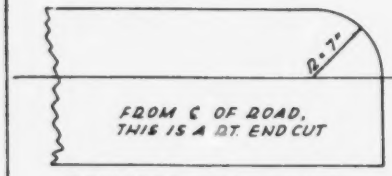


SECTION

RADIUS	MAX. LENGTH
21'	3'
22'- 28'	4'
29'- 35'	5'
36'- 42'	6'
43'- 49'	7'
50'- 56'	8'
57'- 60'	9'
OVER 60'	10'

MINIMUM LENGTH OF CURB STONES - 3'
MAXIMUM LENGTH OF CURB STONES - 10'
MAXIMUM LENGTH OF STRAIGHT CURB STONES LAID ON CURVES - SEE CHART

NOTE: ADJOINING STONES SHALL HAVE THE SAME OR APPROXIMATELY THE SAME LENGTH.

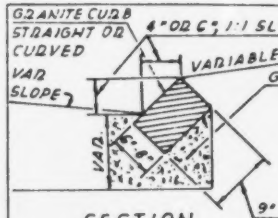


ROUNDED CURB ENDS

NOTE
CURB ENDS TO BE ROUNDED AND BATTERED. FACES TO BE CUT WHEN CALLED FOR ON THE PLANS, SUBSIDIARY.

APPROVED 1-15-79 W. S. Pearson DESIGN ENGINEER	STATE OF NEW HAMPSHIRE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS GRANITE CURB A	REV DATE	STANDARD PLATE S.G.C.-A C.G.C.-A

W.O.P. & E.H.Q. PLATE 1 OF STD. NO. 4



NOTE
ADJOINING STONES OF STRAIGHT CURB LAID ON CURVES SHALL HAVE THE SAME OR APPROXIMATELY THE SAME LENGTH

SECTION

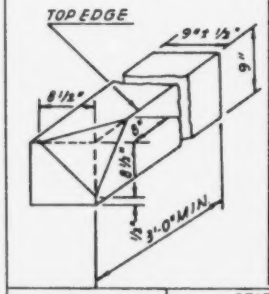
RADIUS FOR STONES WITH SQUARE JOINTS	RADIUS FOR STONES WITH RADIAL JOINTS	MAX LENGTH
16'- 28'	SEE RADIAL CHART PLATE 3 OF STD NO 4	1'-6"
29'- 41'		2'
42'- 55'		3'
56'- 68'		4'
69'- 82'		5'
83'- 96'		6'
97'- 110'		7'
OVER 110'		8'

MINIMUM LENGTH OF STRAIGHT CURB STONES - 18"

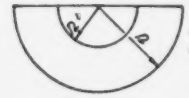
MAXIMUM LENGTH OF STRAIGHT CURB STONES - 8'

MAXIMUM LENGTH OF STRAIGHT CURB STONES LAID ON CURVES - SEE CHART

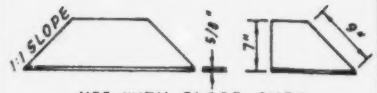
END STONE



DETAIL FOR CUTTING CURVED CURB
FOR 1' OR 1.5' RADIUS - R



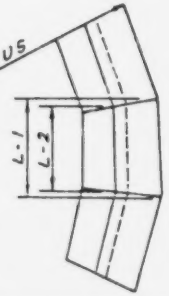
R'= 5 5/8" FOR 1' R
R'= 11 3/8" FOR 1.5' R



USE WITH SLOPE CURB

APPROVED 1-15-79 W. S. Pearson DESIGN ENGINEER	STATE OF NEW HAMPSHIRE DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS GRANITE SLOPE CURB	REV DATE 2-26-75	STANDARD PLATE S.G.S.C. C.G.S.C.

W.O.P. & E.H.Q. PLATE 2 OF STD. NO. 4



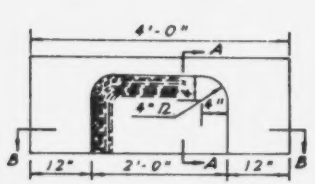
DETAIL OF SKETCH FOR CUTTING STRAIGHT GRANITE SLOPE CURB WITH RADIAL JOINTS. (FOR USE WITH 2' TO 15' RADII)

L-1	RADIUS 2'	2.5'	3'	3.5'	4'	5'	6'	8'	10'	12'	14'	15'
	L-2											
0'-9"	0'-6 15/16"											
1'-0"	0'-8 3/16"	0'-9 1/2"										
1'-1"	0'-9 1/2"	0'-10 3/16"										
1'-2"	0'-10 3/16"	0'-11"	0'-11 13/16"									
1'-3"	0'-11"	0'-11 13/16"	1'-0 1/16"									
1'-4"	0'-11 13/16"	1'-0 13/16"	1'-1 3/16"	1'-1 1/2"								
1'-5"	1'-0 1/2"	1'-1 1/2"	1'-2"	1'-2 1/2"	1'-2 3/16"	1'-3 1/16"	1'-3 13/16"	1'-4"	1'-4"	1'-4 1/16"	1'-4 1/16"	1'-4 1/16"
1'-6"	1'-1 3/16"	1'-2 1/16"	1'-2 13/16"	1'-3 3/16"	1'-3 13/16"	1'-4"	1'-4 13/16"	1'-4 13/16"	1'-5"	1'-5 1/16"	1'-5 1/16"	1'-5 1/16"
1'-7"	1'-2"	1'-3"	1'-3 13/16"	1'-4"	1'-4 13/16"	1'-5"	1'-5 13/16"	1'-5 13/16"	1'-6"	1'-6 1/16"	1'-6 1/16"	1'-6 1/16"
1'-8"	1'-2 13/16"	1'-3 13/16"	1'-4 13/16"	1'-5"	1'-5 13/16"	1'-6"	1'-6 13/16"	1'-6 13/16"	1'-7"	1'-7"	1'-7 1/16"	1'-7 1/16"
1'-9"							1'-7 1/16"	1'-7 1/2"	1'-8"	1'-8"	1'-8 1/16"	1'-8 1/16"
1'-10"							1'-8"	1'-8 1/2"	1'-8 13/16"	1'-9"	1'-9 1/16"	1'-9 1/16"
1'-11"							1'-9"	1'-9 1/2"	1'-9 13/16"	1'-10"	1'-10 1/16"	1'-10 1/16"
2'-0"							1'-10"	1'-10 1/2"	1'-10 13/16"	1'-11"	1'-11"	1'-11"
2'-1"											2'-0"	2'-0"
2'-2"											2'-1"	2'-1"
2'-3"											2'-2"	2'-2"
2'-4"											2'-3"	2'-3"
2'-5"											2'-4"	2'-4"
2'-6"											2'-4 13/16"	2'-5"
2'-7"											2'-5 13/16"	2'-5 13/16"
2'-8"											2'-6 13/16"	2'-6 13/16"

APPROVED 1-15-79	STATE OF NEW HAMPSHIRE	REV DATE	STANDARD
DESIGN ENGINEER	DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS		PLATE
	CUTTING STRAIGHT GRANITE SLOPE CURB WITH RADIAL JOINTS		SGSC RADIAL CHART

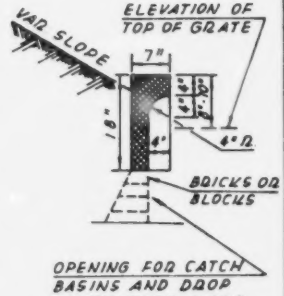
W.O.P. & E.H.D.

PLATE 3 OF STD. NO. 4



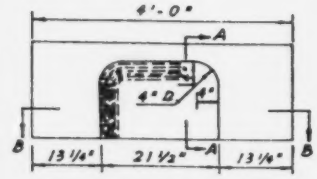
ELEVATION OF TYPE A

TO BE USED WITH CATCH BASIN TYPE A AND DROP INLET TYPE A IF CALLED FOR ON THE PLANS



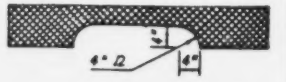
OPENING FOR CATCH BASINS AND DROP INLETS, TYPE A OR B

SECTION A-A



ELEVATION OF TYPE B

TO BE USED WITH CATCH BASIN TYPE B AND DROP INLET TYPE B IF CALLED FOR ON THE PLANS



SECTION B-B

APPROVED 1-15-79	STATE OF NEW HAMPSHIRE	REV DATE	STANDARD
DESIGN ENGINEER	DEPARTMENT OF PUBLIC WORKS AND HIGHWAYS		PLATE
	GRANITE CURB INLETS		C.I.-A C.I.-B

W.O.P. & E.H.D.

PLATE 5 OF STD. NO. 4

Appendix "C"

DEPARTMENT OF NATURAL RESOURCES — MINISTÈRE DES RESSOURCES NATURELLES

NEW BRUNSWICK
CANADA

P.O. Box 6000
Fredericton, N. B.
E3B 5H1

MINERAL RESOURCES DIVISION

June 23, 1982

Ms. Sheralyn E. Yundt
Ontario Ministry of Natural Resources
Room 4646, Whitney Block
99 Wellesley Street West
TORONTO, Ontario M7A 1W3

Dear Sheri:

There is no written documentation on the New Brunswick Department of Transportation concerning the use of granite curbing, but it is their policy on new construction of bridges that where sidewalks are designed in the structure that granite curbing be used. Where there is only a small parapit wall it is difficult to key-in the granite curbing and so it is not specified.

Specifications on granite curbing are covered by Item No. 41 of the General Specifications for the New Brunswick Department of Transportation and a copy of these is enclosed for your information.

If you have further questions in regard to specifications and design then I suggest you contact Mr. Jack Oudemans, Assistant Director - Design Engineer of the New Brunswick Department of Transportation at (506) 453-2674.

Yours sincerely,

Donald E. Barnett
Industrial Mineral
Geologist

DEB/clb

Enclosure

ITEM NO. 41 - - March 1973
GRANITE CURBING

DESCRIPTION

This item consists of installation of granite curbing as shown on the Plans or as directed by the Engineer.

MATERIALS

(a) Granite curb stones will be supplied by the Department of Highways at the Central Bridge Depot, Nashwaaksis, N. B.

(b) Curb stones will be supplied in random lengths of 2'--0" to 6'--0" with at least 50 per cent of the stones longer than 3'--0". An excess of stones will be supplied to provide a choice of lengths.

CONSTRUCTION

(a) The Engineer shall be notified a minimum of 14 days in advance of the Contractor's requirements for granite curbing.

(b) Storage and safekeeping of materials shall be the responsibility of the Contractor.

(c) Curb stones shall be placed so a joint falls at the specified location for curb deflection joints, as shown on the Plans. At curb deflection joints the space between curb stones shall be filled with 1/2 inch neoprene sponge and elastomeric joint sealant. Other joints shall be mortar filled.

(d) Curb stones shall be placed on fresh mortar bedding in proper alignment before the mortar has set. Curb stones and concrete underlying mortar bedding shall be thoroughly wetted with water just before mortar bedding is placed.

(e) Concrete shall not be placed behind curb stones until stones have been in place for at least 48 hours. During this period, precautions shall be taken to ensure stones are not disturbed. If stones are disturbed or joint broken, mortar shall be thoroughly cleaned from bed and stones, and stones reset in fresh mortar.

(f) Curb stones shall be placed so there is a 1/2" ($\pm$ 1/8") space between ends of front faces. Joints shall be pointed at time of placing stones. Pointing mortar shall be applied to wetted end surfaces for a depth of at least two inches and shall be driven in place and finished flush with pitch line of stones.

(g) Joint mortar shall consist of 1 part Portland Cement to 3 parts sand, with water as necessary to obtain required

(d) The finished surface of the concrete slope protection must have no greater deviation than 1/2 inch in 10 feet.

MEASUREMENT

(a) The quantities to be measured for payment shall be the number of square feet of precast concrete slope protection acceptably placed in the work as shown on the Plans or as directed by the Engineer.

(b) The grading of the slopes and the supply, placing, grading and compacting of the 4 inch bed of sand under the precast blocks will not be measured for payment but shall be considered as incidental to the work.

(c) The supply and placing of the sand-cement mortar in the joints between the precast blocks will not be measured for payment.

(d) Concrete aggregate, cement, formwork, mixing, placing, curing and protection will be as specified in Item No. 29, Cement, and Item No. 30, Concrete In Structures, and will not be measured for payment but shall be considered as incidental to the work.

ITEM NO. 43
CONCRETE GRADE BEAMS

DESCRIPTION

This item consists of the excavating for, forming, supplying of concrete, placing and furnishing of the concrete for the grade beams as shown on the Plans or as directed by the Engineer.

MATERIALS

(a) Materials shall be supplied by the Contractor.

(b) Concrete shall have a 28 day compressive strength of 3,500 p.s.i., a maximum size aggregate of 3/4 inch and an entrained air content of 6-1/2 $\pm$ 1 per cent. Concrete shall be in accordance with Item No. 30, Concrete In Structures.

CONSTRUCTION

(a) The Contractor shall excavate for the concrete grade beams and keep the excavation as close as practicable to the size of the grade beams.

(b) The Contractor may use approved wood or steel forms for the grade beams. When the Engineer deems that the undisturbed

PROVINCE OF NEW BRUNSWICK ITEM NO. 41

DEPARTMENT OF TRANSPORTATION GRANITE CURBING

GENERAL SPECIFICATIONS

DESCRIPTION

This item consists of installation of granite curbing as shown on the Plans or as directed by the Engineer.

MATERIALS

(a) Granite curb stones will be supplied by the Department of Transportation at the Central Bridge Depot, Fredericton, N. B.

(b) Curb stones will be supplied in random lengths of 0.6 m to 2 m with at least 50% of the stones longer than 1 m. An excess of stones will be supplied to provide a choice of lengths.

(c) Mortar sand shall meet the requirements of Item 30, Fine Aggregate except for the following:

Grading Limits:

Sieve Size	Total Passing Sieve Percent by Weight
4.75 mm	100
2.36 mm	95-100
1.18 mm	60-100
600 um	35-80
300 um	15-50
150 um	2-15

Note: Fine aggregate shall be so graded that neither the proportion of particles finer than a 1.18 mm sieve and coarser than a 600 um sieve, not the proportion finer than a 600 um sieve and coarser than a 300 um sieve, exceeds 50%.

Fineness modulus shall not be less than 1.6 or more than 2.5. If the fineness modulus varies by more than + 0.20 from the value established at the beginning of production, the sand shall be rejected.

CONSTRUCTION

(a) The Engineer shall be notified a minimum of 14 days in advance of the Contractor's requirements for granite curbing.

(b) Storage and safekeeping of materials shall be the responsibility of the Contractor.

(c) Curb stones shall be placed so a joint falls at the specified location of curb deflection joints, as shown on the Plans. At curb deflection joints the space between curb stones shall be filled with 12.7 mm neoprene sponge and elastomeric joint sealant. Other joints shall be mortar filled.

(d) Curb stones shall be placed on fresh mortar bedding in proper alignment before the mortar has set. Curb stones and concrete underlying mortar bedding shall be thoroughly wetted with water just before mortar bedding is placed.

(e) Concrete shall not be placed behind curb stones until stones have been in place for at least 48 hours. During this period, precautions shall be taken to ensure stones are not disturbed. If stones are disturbed or joint broken, mortar shall be thoroughly cleaned from bed and stones, and stones reset in fresh mortar.

(f) Curb stones shall be placed so there is a 13 mm ($\pm$ 3 mm) space between ends of front faces. Joints shall be pointed at time of placing stones. Pointing mortar shall be applied to wetted end surfaces for a depth of at least 50 mm and shall be driven in place and finished flush with pitch line of stones.

(g) Mortar shall consist of one part Type 10 Portland Cement to one part masonry cement to 2 1/2 to 3 parts sand, with water as necessary to obtain the required consistency. Air entraining mixture shall be used to produce an air content of 12% $\pm$ 2%. Cementitious materials and aggregate shall be mixed for a minimum of three minutes with the necessary amount of water to produce a workable consistency in a mechanical mortar mixer. Mortar shall be used within 30 minutes after preparation.

MEASUREMENT

(a) The quantities to be measured for payment shall be the number of lineal metres of granite curbing, complete in place, acceptably installed to the satisfaction of the Engineer.

(b) Supply of materials for mortar, admixtures, mixing and application of mortar to install, bed and point granite curbing will not be measured for payment but shall be considered as incidental to the work.

(c) Loading, delivery to site, unloading, storage, reloading and distribution of granite curbing will not be measured for payment but shall be considered as incidental to the work.

(d) Granite curbing not incorporated in the work shall be returned to the Department of Transportation, Central Bridge Depot, Fredericton, N. B. Reloading and returning granite curbing will not be measured for payment but shall be considered as incidental to the work.

(e) Any recesses necessary for installation of granite curbing will be formed when the deck is cast and shall be considered incidental to the work.

Dick Bennett

STATE OF MAINE
DEPARTMENT OF TRANSPORTATION
TRANSPORTATION BUILDING
STATE HOUSE STATION 16 AUGUSTA, MAINE 04333

GEORGE N. CAMPBELL, JR.
Commissioner

September 29, 1982

Ministry of Natural Resources
P. O. Box 5160
Kenora, Ontario
P9N 3X9

Gentlemen:

Enclosed please find the material which you have requested. For any additional information required, please do not hesitate to contact me at this office.

Very truly yours,

Louis L. Poulin

Louis L. Poulin
Office Engineer
Bureau of Construction

LLP/cab

cc: File

Enclosure

MINISTRY OF NATURAL RESOURCES
RECEIVED
OCT - 6 1982
REGIONAL OFFICE, KENORA

CURBING COMMENTS

1. Granite is used for curbing and for protection around bridge piers and abutments in salt water to protect the concrete from salt water damage.

2. Practically all bridge curbing is granite.

3. 6700 linear feet of bridge curbing was installed on new construction in 1982. This work is done by contract on individual bridges.

4. We do not use any portland cement concrete curbing. It was tried and found to be unsatisfactory. Bituminous cement curbing is used extensively; 53,000 linear feet in 1982.

5. Joints in bridge curbing must be repointed every 25 years or so.

6. There is no special weight problem with granite bridge curb.

7. Except for repointing bridge curbing, there are no special maintenance problems with granite curb. Occasionally it might have to be relaid due to settlement.

8. We have no special figures on maintenance of curbing.

Comment: Due to the high cost of granite curb, we try to use bituminous curb wherever possible. Although granite curb lasts longer, we find bituminous curbing performs satisfactorily. In the 1950's, granite curb was used in volumes which would support local quarries but recently due to the high price and use of bituminous curbing, local quarries have ceased operations. Most of our granite comes from out-of-State.

Quantities used in 1982:

Granite highway curb	-	20,000 l.f.
Granite highway edging	-	23,000

Prices: Granite highway curb	-	$14.50/l.f.
Granite bridge curb	-	15.00/l.f.
Bituminous highway curb	-	1.75/l.f.
Granite highway edging	-	5.50/l.f.

SECTION 609 -- CURBING

609.01 Description. This work shall consist of furnishing and installing curb or edging, or removing and relaying existing curbing or edging on highways and bridges in accordance with these specifications and in reasonably close conformity with the lines and grades shown on the plans or established. The types of curb are designated as follows:

Type 1-Stone curbing of quarried granite stone
Type 3-Bituminous curbing
Type 5-Stone edging of quarried granite stone

MATERIALS

609.02 Materials. Except as provided below, the materials used shall meet the requirements of the following Subsections of Division 700 -- Materials:

Joint Mortar	705.02
Reinforcing Steel	709.01
Stone Curbing and Edging	712.04
Epoxy Resin	712.35
Bituminous Curbing	712.36

Circular curb, terminal sections and transition sections shall be in reasonably close conformity with the shape and dimensions shown on the plans and to the applicable material requirements herein for the type of curb specified.

Dowels shall be reinforcing steel deformed bars.

CONSTRUCTION REQUIREMENTS

609.03 Vertical Stone Curb, Terminal Section and Transition Sections.

(a) Installation. The curb stone shall be set on a compacted foundation so that the front top arris line conforms to the lines and grades required. The foundation shall be prepared in advance of setting the stone by grading the proper elevation and shaping to conform as closely as possible to the shape of the bottom of the stone. The required spacing between stones shall be assured by the use of an approved spacing device to provide an open joint between stones of at least 1/4 inch and no greater than 5/8 inch.

(b) Backfilling. All remaining spaces under the curb shall be filled with approved material and thoroughly hand tamped so the stones will have a firm uniform bearing on the foundation for the entire length and width. Any remaining excavated areas surrounding the curb shall be filled to the required grade with approved materials. This material shall be placed in layers not exceeding 8 inches in depth, loose measure and thoroughly tamped.

When backfill material infiltrates through the joints between the stones, small amounts of joint mortar or other approved material shall be placed in the back portion of the joint to prevent such infiltrating.

(c) Protection. The curb shall be protected and kept in good condition. All exposed surfaces smeared or discolored shall be cleaned and restored to a satisfactory condition or the curb stone removed and replaced.

(d) Curb Inlets. Curb placed adjacent to curb inlets shall be installed with steel dowels cemented into each stone with epoxy grout as shown on the Standard Detail plans.

The epoxy grout shall be used in accordance with the manufacturer's instructions. The grout shall be forced into the hole, after which the dowel shall be coated with grout for one-half its length and inserted into the grout filled hole. The hole shall be completely filled with grout around the dowel. All tools and containers must be clean before using.

609.04 Bituminous Curb.

(a) Preparation of base. Prior to placing the curb, the foundation course shall be thoroughly cleaned of all foreign and objectionable material. String or chalk lines shall be positioned on the prepared base to provide guide lines. The foundation shall be uniformly painted with tack coat as specified under Section 410 -- Bituminous Surface Treatment.

(b) Placing. The curb shall be placed by an approved power operated extruding type machine. A tight bond shall be obtained between the base and the curb. The Engineer may permit the placing of curbing by other than mechanical curb placing machines when short sections or sections with short radii are required. The resulting curbing shall conform in all respects to the curbing produced by the machine.

(c) Sealing. The curb shall be sealed with bituminous sealing compound, when directed in accordance with Section 612 -- Bituminous Sealing. Before sealing, the curbing shall be clean, dry and the bituminous material shall have reached the ambient temperature.

(d) When required, the curb shall be painted and coated with glass beads in accordance with Section 627 -- Pavement Marking. Curb designated to be painted shall not be sealed with bituminous sealing compound before the curb is painted.

(e) Acceptance. Curb may be accepted or rejected on the basis of appearance in regard to texture and/or alignment. All damaged curb shall be removed and replaced at the Contractor's expense.

609.05 Vacant

609.06 Stone Edging. The curb shall be installed, backfilled and protected in accordance with Subsection 609.03, except as follows:

(a) Slope. The edging shall be set on a slope as shown on the plans or as directed.

(b) Joints. Joints shall be open and not greater than 1/2 inch in width.

609.07 Stone Bridge Curb.

(a) Installation. Each stone and the bed upon which it is to be placed shall be cleaned and thoroughly wetted with water prior to placing the mortar for bedding and setting the stone. The stone shall be set on a fresh bed of joint mortar and well bedded before the mortar has set so that the front top arris line conforms to the line and grade required. Whenever temporary supporting wedges or other devices are used in setting the stones they shall be removed before the mortar in the bed has become set and the holes left by them shall be filled with mortar. Concrete behind the stones shall not be placed until the stones have been in place at least 2 days. Bedding and pointing mortar for joints shall be cured as required under Section 502 -- Structural Concrete.

(b) Joints. Vertical joints shall be 1/2 inch in width plus or minus 1/8 of an inch. Whenever possible the face and top of the joint shall be pointed with joint mortar to a depth of 1 1/2 inches, before the bedding mortar has set. Joints which cannot be so pointed shall be prepared for pointing by raking them to a depth of 1 1/2 inches before the mortar has set. Joints not pointed at the time the stone is laid shall be thoroughly wetted with clean water and filled with mortar. The mortar shall be well driven into the joint and finished with an approved pointing tool, flush with the pitch line of the stones.

609.08 Resetting Stone Curb, Including Terminal Sections and Transitions.

(a) Removal of Curbing. The Contractor shall carefully remove and store curb specified on the plans or designated for resetting. Curb damaged or destroyed, as a result of the Contractor's operations or because of his failure to store and protect it in a manner that would prevent its loss or damage, shall be replaced with curbing of equal quality at the Contractor's expense.

(b) Excavation. Necessary excavation shall be made to the required depth and the base upon which the curb is to be set shall be compacted to a firm, even surface. All soft and unsuitable material shall be removed and replaced with suitable material which shall be thoroughly compacted.

(c) Setting Curb. The curb shall be set and backfilled in accordance with Subsection 609.03 or 609.06 whichever is applicable.

(d) Cutting and Fitting. Cutting or fitting necessary in order to install the curbing at the locations directed shall be done by the Contractor.

609.09 Method of Measurement. Curb, both new and reset will be measured by the linear foot along the front face of the curb at the elevation of the finished pavement, complete in place and accepted. Curb inlets at catch basins, including doweling, will not be measured for payment, but shall be considered included in the cost of the catch basin. New transition sections and terminal curb will be measured by the unit. Reset transition sections and terminal curb will be included in the measurement for resetting curb.

609.10 Basis of Payment. The accepted quantities of curbing will be paid for at the contract unit price per linear foot for each kind and type of curbing as specified.

Payment for terminal curb shall include only that portion of the curbing modified for installation at ends of curb runs shown on the detail plans. Curb adjacent to terminal ends shall be paid for at the contract unit price per linear foot for the type of curb installed.

Vertical Curb Type 1 required to be placed on a radius of 60 feet or less, will be paid for as Vertical Curb-Circular-Type 1.

Curb, Type 5 required to be placed on a radius of 30 feet or less will be paid for as Curb Circular, Type 5.

There will be no separate payment for cement, reinforcing steel, anchors, tack coat, drilling for and grouting anchors, jointing and bedding of curbing, and for cutting and fitting, but these will be considered included in the work of the related curb.

Necessary excavation for installing new or reset curbing will not be paid for directly, but shall be considered to be included in the appropriate new or reset curb pay item. Base and Subbase material will be paid for under Section 304 -- Aggregate Base and Subbase Course.

Payment will be made under:

Pay Item		Pay Unit
609.11	Vertical Curb Type 1	Linear Foot
609.12	Vertical Curb Type 1-Circular	Linear Foot
609.13	Vertical Bridge Curb Type 1	Linear Foot
609.14	Vertical Bridge Curb Type 1-Circular	Linear Foot
609.15	Sloped Curb Type 1	Linear Foot
609.23	Terminal Curb Type 1	Each
609.26	Curb Transition Section B Type 1	Each
609.31	Curb Type 3	Linear Foot
609.34	Curb Type 5	Linear Foot
609.35	Curb-Type 5-Circular	Linear Foot
609.38	Reset Curb Type 1	Linear Foot
609.40	Reset Curb Type 5	Linear Foot

SECTION 610 -- STONE FILL, RIPRAP, STONE BLANKET AND STONE DITCH PROTECTION

610.01 Description. This work shall consist of excavating for and constructing a protective covering of stone, with or without grout.

Testing shall be performed in accordance with the applicable sections of ASTM A 370. Tensile test of finished studs shall be made as described in AASHTO Standard Specifications for Highway Bridges, 2.10.3(11)(6).

If fracture occurs outside the middle half of the gage length, the test shall be repeated.

An arc shield (ferrule) of heat-resistant ceramic or other suitable material shall be furnished with each stud. The material shall not be detrimental to the welds or cause excessive slag and shall have sufficient strength so as not to crumble or break due to thermal or structural shock before the weld is completed.

Flux for welding shall be furnished with each stud, either attached to the end of the stud or combined with the arc shield; for automatic application in the welding operation.

SECTION 712 -- MISCELLANEOUS HIGHWAY MATERIAL

712.01 Vacant

712.02 Calcium Chloride. Calcium chloride shall conform to the requirements of AASHTO M 144 (ASTM D 98).

712.03 Vacant

712.04 Stone Curbing and Edging. Stone for curbing and edging shall be approved granite from acceptable sources. The stone shall be hard and durable, predominantly gray in color, free from seams which impair its structural integrity and of smooth splitting character. Natural grain size and color variations characteristic of the source deposit will be permitted. Such natural variations may include bands or clusters of mineral or both of mineral crystalization that do not impair the structural integrity of the curb stone. The dimensions, shape and other details shall be as shown on the plans.

The exposed face of stone curb shall be free from indications of drill holes. Half drill holes not larger than 3/4 inch diameter will be permitted in the arris line in the plane of the back.

(a) Vertical Curb, Type 1 shall have a top surface sawed or dressed to an approximate true plane with no depression or projection on that surface of over 1/8 inch. The top front arris line shall be pitched straight and true with no varitions from a straight line greater than

1/4 inch. The top back arris line shall meet the same requirement except that indentations of a maximum of 3/8 inch will be allowed. There shall be no projection or depression on the back face which would exceed a batter of 1 horizontal on 3 vertical for a distance from the top of 3 inches.

The front face shall be at right angles to the top and shall be smooth split and have no projections greater than 1 inch or depressions greater than 1/2 inch, measured from the vertical plane of the face through the top arris line, for a distance down from the top of 8 inches. The remainder of the face shall have no projections or depressions greater than 1 inch from the plane of the face.

The ends of the curb shall be approximately square with the planes of the top, back and face and so finished that when the sections are placed end to end with the required minimum spacing of 1/4 inch no more than 5/8 inch space shall show in the joint for the full width of the top surface and for the entire exposed front face. The remainder of the end may extend back no more than 8 inches from the plane of the joint.

Drill holes through the curb will be allowed providing they are at least 9 inches below the top and are mortared full with portland cement mortar before placing the stone.

(b) Miscellaneous Stone Curb. When a depressed or modified section of curb is called for on the plans or ordered by the Engineer, for driveways, crossings, closures, transitions or for other reasons, the Contractor shall furnish curbing with the required modifications.

(c) Curb Inlets. Inlets used at catch basins shall conform to the applicable requirements of Vertical Curb, Type 1 and to the shape, dimensions and details as shown on the Standard Detail plans.

(d) Vacant

(e) Vertical Bridge Curb, Type 1 shall conform to the requirements above, except as indicated on the plans and as follows:

1. The back face of the curb stones shall have no projections or depressions greater than 1 inch, measured from the vertical plane of the back face through the arris or pitch line down to the bottom of the stone. The front face shall be finished as required for Vertical Curb, Type 1, except that it shall be finished the full distance down on the face. Bottoms of curb stones shall be approximately parallel to the top and sawed or dressed to lay with a bedding of approximately 1 inch for the full length of the stone.

2. Anchor holes shall be provided in the back of the stones pitched down as shown on the plan, a maximum of 12 inches from each end of the stone and spaced horizontally at approximately 2 feet apart. A minimum of 2 anchor holes shall be provided in each stone.

3. The ends of stones at expansion joints between spans and at ends of bridge shall be cut to present a vertical face when set in position, bevelled to the skew angle, if any and the entire end finished in the same manner as the top.

4. The exposed edges of the stones at intermediate joints shall be trimmed square with the planes of the top and front face so that a neat, parallel joint, free from drill holes is formed between the stones. Length of stones shall be so scheduled that joints will be uniform in width along any run of curb. Joints shall be 1/2 inch, plus or minus 1/8 inch. A joint shall be provided at each curb and sidewalk contraction joint of the bridge.

5. Stones set transversely at ends of bridge, when the grade exceeds 2 percent, shall have the top bevelled to fit the grade of the bridge.

6. Mortar for bedding shall be composed of 1 part portland cement and 2 parts sand with sufficient water to form a workable mix. Cement, sand and water shall conform to Section 502 -- Structural Concrete.

7. Mortar for pointing shall be composed of equal parts sand and portland cement with sufficient water to form a workable mix and shall conform to Section 502 -- Structural Concrete.

8. Portland cement grout shall be made the same as mortar for pointing, except that consistency shall be such that it will flow readily.

(f) Curb Type 5. The exposed face shall be smooth split to an approximate true plane having no projections or depressions which will allow over 1 inch to show between a 2 foot straightedge and the face when the straightedge is placed as closely as possible on any part of the face. Half drill holes not more than 3 inches in length and 3/4 inch in diameter will be permitted along the bottom. The arris line, top front shall be straight and true with no variation from a straight line greater than 1/8 inch. The arris lines at the bottom of the face shall be straight and true so that not over 1 inch shall show between the stone and a straightedge for the full length of the stone. The ends shall be square to the length at the face and so finished that when the stones are placed end to end, no space more than 1 1/2 inches will show in the joint for the width of the face.

When Curbing Type 5 is required on a curve, the pieces shall be shaped as described in the table on the Standard Detail plans.

712.05 Reflectorized Plastic Pavement Markings. The reflectorized plastic final pavement marking material shall conform to AASHTO standards and shall be a retro-reflective, prefabricated, conformable polymer thermoplastic consisting of polymeric materials, pigments, reflective glass spheres uniformly distributed throughout the entire cross section with a reflective layer of glass spheres bonded to the top surface and shall be capable of being affixed to bituminous pavement and concrete pavement by a pressure sensitive precoated adhesive or a liquid contact cement. The reflectorized marking material shall be plastic of the cold applied preformed type as compared to the hot applied extruded or sprayed thermoplastic.

The reflectorized plastic final pavement marking material shall be capable of conforming to pavement contours, breaks and faults and shall have resealing characteristics. The top surface of the plastic shall have maximum glass sphere retention qualities, shall have a matte finish and shall be a minimum of 60 mils thick without adhesive.

The reflectorized plastic final pavement marking material shall have the following initial minimum reflectance values at 0.2° observation angle and 86.0° entrance angle as measured in accordance with the testing procedures of Federal Test Method Standard 370. The photometric quantity to be measured shall be specific luminance (SL) and shall be expressed as millicandelas per square foot per foot-candle (mcd ft^{-2} fc^{-1}). The test distance shall be 50 ft. and the sample size shall be a 2.0 x 2.5 ft. rectangle.

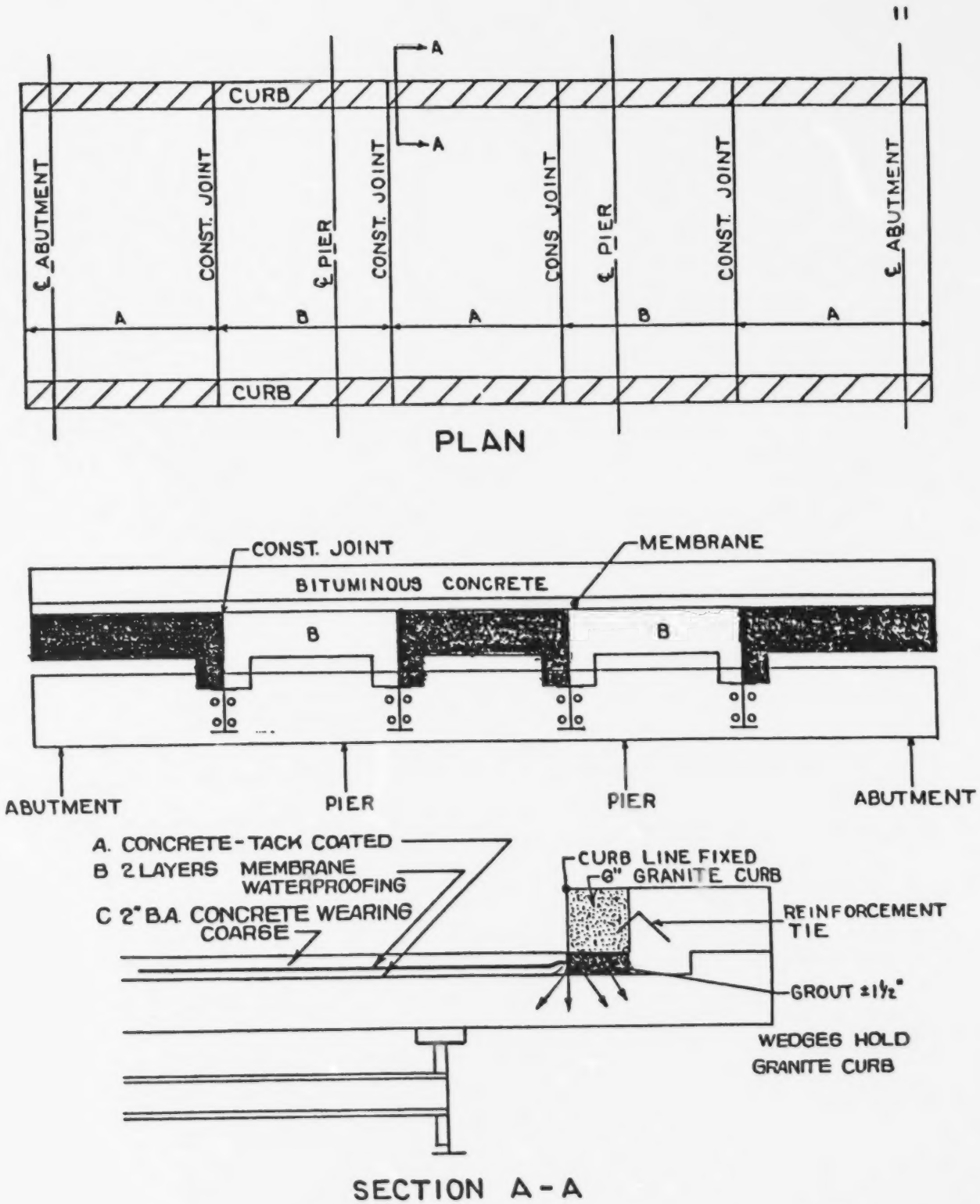


Figure 2 Bridge deck details showing alternate panels, granite curb and membrane & paving

Appendix "E"

STATE OF VERMONT
AGENCY OF TRANSPORTATION
133 State Street, Administration Building
Montpelier, Vermont 05602

RECEIVED
JUL 21 19

July 15, 1982

Ministry of Natural Resources
P.O. Box 5160
Kenora, Ontario P9N3X9

Attention: R. C. Beard, Mineral Resources Coordinator

Re: Use of Granite and other Stone Products
Letter of July 7, 1982

Dear Mr. Beard:

In reply to your recent letter, we wish to furnish the following information.

The only use of natural stone, other than crushed stone for stone base or as an aggregate for concrete, is bridge or roadway curbing.

We have used bridge curbing on 321 miles of Interstate and other major bridges on our Primary and Secondary Highway Systems. It is used primarily to provide a curb highly resistant to abrasion of snow plow blades.

Granite is used due to the ease of splitting in straight rock face planes. Color is usually grey due to availability. Other colors would be acceptable. Roughly 25% of our bridge curbing has been granite. Approximately 1100 linear feet is used annually. Granite curbing is furnished and set by the contractors on a linear foot payment basis on each contract.

Granite bridge curbing is attached to a concrete backing and is held securely in place with virtually no maintenance required. Granite roadway curbing is mainly used at the gutter line of sidewalks and may require resetting after a period of twenty years. Usually no granite curb requires replacement.

Granite usually takes the place of the same volume of concrete when used as bridge curb. Differences between weight of granite and concrete are negligible, hence it does not require special designs due to weight.

Granite bridge curb is not used on low traffic volume rural roads mainly due to the extra initial cost.

We do not have a comparison of short term and long term costs between concrete and granite curbs. However in 30 years of granite bridge curb use, we have not replaced a granite bridge curb. It appears that the granite curb will out last the concrete bridge deck. We have, however, replaced many concrete bridge curbs 40 to 50 years old with severe slab edge and concrete curb disintegration at a cost several times the cost of granite curb.

Initial costs of granite bridge curb is approximately $18/LF more than a concrete bridge curb. Design details are enclosed.

Hopefully we have supplied the information you are seeking to the best of our records. If you have further questions, please contact us by phone.

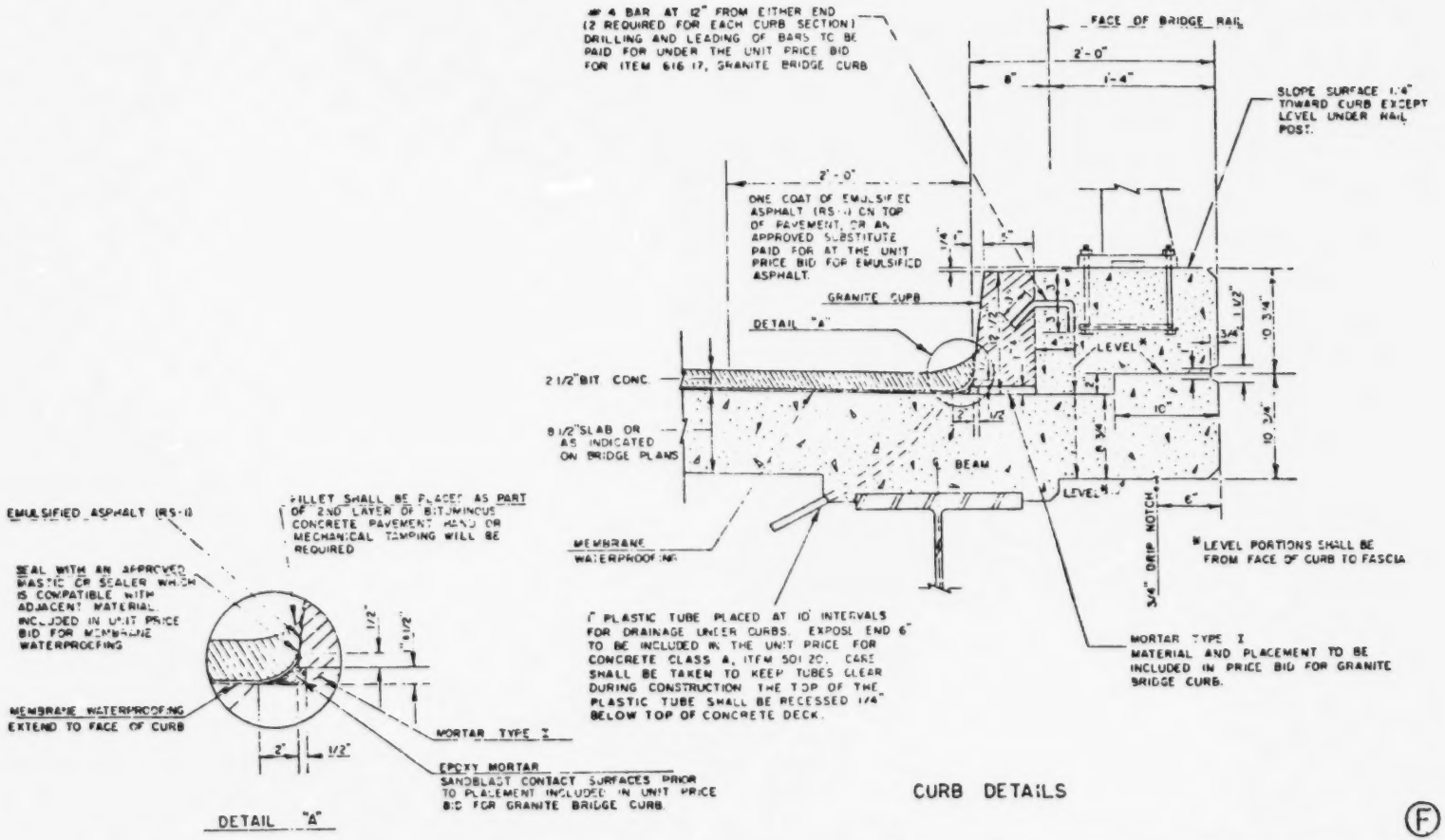
Sincerely,

Wendell M. Smith

Wendell M. Smith
Structures Engineer
(802) 828-2621

Attachment

WMS:mm


#4 BAR AT 12" FROM EITHER END (2 REQUIRED FOR EACH CURB SECTION) DRILLING AND LEADING OF BARS TO BE PAID FOR UNDER THE UNIT PRICE BID FOR ITEM 616 17, GRANITE BRIDGE CURB
FACE OF BRIDGE RAIL
2'-0"
8"
1'-4"
SLOPE SURFACE 1/4" TOWARD CURB EXCEPT LEVEL UNDER RAIL POST.
2'-0"
ONE COAT OF EMULSIFIED ASPHALT (RS-1) ON TOP OF PAVEMENT, OR AN APPROVED SUBSTITUTE PAID FOR AT THE UNIT PRICE BID FOR EMULSIFIED ASPHALT.
GRANITE CURB
DETAIL "A"
2 1/2" BIT CONC
8 1/2" SLAB OR AS INDICATED ON BRIDGE PLANS
LEVEL*
10"
℄ BEAM
LEVEL*
6"
3/4" DRIP NOTCH
MEMBRANE WATERPROOFING
1" PLASTIC TUBE PLACED AT 10' INTERVALS FOR DRAINAGE UNDER CURBS. EXPOSE END 6" TO BE INCLUDED IN THE UNIT PRICE FOR CONCRETE CLASS A, ITEM 501 20. CARE SHALL BE TAKEN TO KEEP TUBES CLEAR DURING CONSTRUCTION. THE TOP OF THE PLASTIC TUBE SHALL BE RECESSED 1/4" BELOW TOP OF CONCRETE DECK.
MORTAR TYPE I MATERIAL AND PLACEMENT TO BE INCLUDED IN PRICE BID FOR GRANITE BRIDGE CURB.
*LEVEL PORTIONS SHALL BE FROM FACE OF CURB TO FASCIA
EMULSIFIED ASPHALT (RS-1)
FILLET SHALL BE PLACED AS PART OF 2ND LAYER OF BITUMINOUS CONCRETE PAVEMENT. HAND OR MECHANICAL TAMPING WILL BE REQUIRED
SEAL WITH AN APPROVED MASTIC OR SEALER WHICH IS COMPATIBLE WITH ADJACENT MATERIAL. INCLUDED IN UNIT PRICE BID FOR MEMBRANE WATERPROOFING
1/2"
1/2"
MEMBRANE WATERPROOFING EXTEND TO FACE OF CURB
MORTAR TYPE I
2"
1/2"
EPOXY MORTAR SANDBLAST CONTACT SURFACES PRIOR TO PLACEMENT INCLUDED IN UNIT PRICE BID FOR GRANITE BRIDGE CURB
DETAIL "A"

CURB DETAILS

(F)

VERMONT AGENCY OF TRANSPORTATION

STANDARD

SCB-D6-73

Translation of letter from Quebec Ministry of Transportation

Quebec City, September 9, 1982

TO: R.C. Beard
Mineral Resources Coordinator
Northwestern Region
P.O. Box 5160
Kenora, Ontario
P9N 3X9

SUBJECT: Utilization of Granite
Your reference 6.3.3.25

Dear Sir,

In reply to your letter dated July 7 concerning the utilization of granite for road construction.

The Quebec Ministry of Transportation utilizes granite exclusively for the construction of curbs on main highways, especially roads subjected to salts and abrasives in large qualities during the winter season.

The utilization of granite curbing is not exclusive; its use, along with concrete curbs poured in place and prefabricated concrete curbs, is the choice of the contractor according to the options described in the appendix.

This option formula is not perfect and its application can favour granite curbs, particularly when the cost of the curbing surpasses 10% of the total contract.

Here are a few statistics on quanities tendered, made up for the Quebec Ministry of Transportation for curbs constructed under this option:

Fiscal year 1979

- Cement curbing poured in place
  4,395 metres at $12.32 = $54,146.40
- Prefabricated concrete curbing
  12,845 metres at $26.61 = $341,805.45
- Granite curbing
  67,250 metres at $35.95 = $2,417,637.50

. . . 2

Fiscal year 1980

- Cement curbing poured in place
  50,992 metres at $14.31 = $729,695.52
- Prefabricated concrete curbing
  33,977 metres at $23.92 = $812,729.82
- Granite curbing
  75,549 metres at $39.02 = $2,947,921.98

Fiscal year 1981

- Cement curbing poured in place
  58,110 metres at $14.72 = $855,379.20
- Prefabricated concrete curbing
  17,503 metres at $28.76 = $503,386.28
- Granite curbing
  19,250 metres at $59.91 = $1,153,267.50

Needless to say, granite curbing does not cause many maintenance problems where as poured concrete must be replaced after a period of approximately twelve years and prefabricated concrete curbs have to be replaced in approximately eighteen years. These figures serve as a base to establish the formula of options for the construction of curbs.

Yours very truly,

Guy Bourgault, ing., adj. a.

Translation

CLAUSE A

Curbs and Rounded Ends

The tenders for curbing make no distinction between straight curbs, curbed curbs, centre islands or boulevards, _____ _____ _____, and it excludes prefabricated rounded ends where the radius is 500 mm to 1,000 mm. These rounded ends require a special contract and the price per unit includes excavation, material supplied, installation of the base course, and all incidential expenses.

When there is a choice as to what type of curbing to use, the builder must submit one of the following options:

- Option #1 Concrete curbs molded in place
- Option #2 Prefabricated concrete curbs
- Option #3 Prefabricated granite curbing

NOTE: Concrete curbs poured in place are not accepted options.

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In the tender, the quanities shown for molded concrete curbing represents 140% of the true quanity of curbing to be installed. The quoted price applies to the effective quanity to be installed.

In the tender, the quanity described for prefabricated granite curbing represents 60% of the true quanity to be installed. The price submitted takes into account only the quanity actually to be installed. In cases where options include rounded curbing, the unit price refers to actual quanities to be installed and is not adjusted by the factors given above.

Appendix "A"
(English Translation)

Government of Quebec
Ministry of Transportation

Appendix

Quebec City, January 14, 1980

TO: Mr. Rene Blais, Engineer
Director General of Operations

FROM: The Director of Construction

SUBJECT: Your reference: 6.3.3.25
Curbing

We have studied the reports submitted by the firms of Montco of Montreal and Page of Quebec City concerning prefabricated concrete curbing and in the difficulty in contracting the work because of the option procedures and equivalent factors.

If it were not for this procedure, only molded concrete curbing or concrete curbing poured in place would be utilized with few exceptions, because of the low initial cost of this type of construction compared to other types of curbing.

The Ministry is interested only in building useful and durable curbing at the lowest possible cost, and curb construction must not escape this rule.

There is only one reason to construct curbing with a higher initial cost, and that is if the total overall cost, over a period of useful years, is identical to or less than other alternatives.

When we construct a highway, we plan for a useful life of at least 35 years. Consequently, all structural work on the road should normally last 35 years plus one year (36 years), without having a greater durability to avoid unnecessary expenses and without having a lesser durability unless the initial cost plus the replacement costs over a 35 year period does not surpass the initial cost of the special installation.

The situation is as follows, for work on curbing:

1 - Type A curbing requires a durability of 36 years; it should not have a durability of less to avoid replacing, and it should not have a higher durability to avoid discarding still useful and valuable material.

2 - Type B curbing requires a durability of 18 years; it should not have a lesser durability to avoid replacing more than once in 36 years, and it should not have a durability of more than 18 years unless it can last for 36 years to avoid unnecessary costs.

. . . 2

3 - Type C curbing requires a durability of at least 12 years permitting two replacements in 36 years. It should not have a durability of more than 12 years unless it can last 18 years, in order to avoid unnecessary costs.

4 - Type D curbing requires a durability of _____ _____ _____.

If we continue our policy of cost equivalency between the different types of curbing for the same period of utilization and our option policy permitting each contractor to select his option according to Ministry specifications, then the cost of installing curbs of type A, the cost of installing plus replacing after 18 years the curbs of type B, and the cost of installing plus replacement cost in 12 years and 24 years of curbs of type C, and the cost of ... etc.... of the curbs of type D, must end up being identical.

The parameters and conditions of such a policy are:

Type A Curbing - Durability 36 years. No replacement.

Type B Curbing - Durability 18 years. One replacement.

Type C Curbing - Durability 12 years. Two replacements.

Type D Curbing - Durability unknown.

Type A Curbing - Highest cost of installation.

Type B Curbing - Intermediate cost of installation.

Type C Curbing - Lowest cost of installation.

Type D Curbing - Unknown cost of installation.

All curbs of lesser cost will be used rather than curbs of higher cost if the durability is the same.

Cost of replacement: installation cost plus 30% for repair work on adjacent curbing exclusive of the unit price of installation.

Real accumulation of capital: interest rate of 3.5% without inflation or 3.5% above inflation rate.

P : Actual price of installation as indicated in the submission.

P = P_a : ...of type A curbing

P = P_b : ...of type B curbing

P = P_c : ...of type C curbing

Q : Actual quanity of curbing, in meters, to be installed.

Q = Q_c ...of curbing of type C as indicated in the submission.

Q_a = Adjusted quanity of type A curbing as per the equivelancy factor applied to the actual quanity.

. . . 3

Q_b = Adjusted quanity of type B curbing, as per the equivalency factor applied to the actual quanity.

QP_c = $Q_aP_a = Q_bP_b = Q_cP_c$ = grand total indicated for curb construction for one submission.

Present value of $1.00 spent in 24 years : 0.4380
Present value of $1.00 spent in 18 years : 0.5384
Present value of $1.00 spent in 12 years : 0.6618

According to these parameters and conditions, the equation is:

$Q_cP_a = Q_cP_b(1+1.3(0.5384)) = Q_cP_c(1+1.3(0.4380+0.6618))$

$Q_cP_a = 1.6999Q_cP_b = 2.4297Q_cP_c$

$Q_cP_c = 1.6996Q_cP_b = 0.4116Q_cP_a$

$Q_c = Q$ (real quanities, in meters)
$Q_b = 0.70Q$
$Q_a = 0.40Q$

Type A curbing is constructed and installed according to specification number D-3501 (79.09.01) and must have a durability of 36 years (granite curbing) ($Q_a = 0.40Q$).

Type B curbing is constructed and installed according to specification number D-3500 (79.09.01) and must have a durability of 18 years (pre-fabricated concrete curbing) ($Q_b = 0.70Q$).

Type C curbing is constructed and installed according to specification number D-3503 (79.09.01) and must have a durability of 12 years (concrete curbing poured in place) ($Q_c = Q$).

If the study and the preceding calculations adequately addresses the needs and policies of the Ministry for the construction of curbing, we request approval and sufficient time to permit modification of directive number 10.04.04R (1978.10.18), concerning the policy on options and equivalency factors related to construction work on curbing, before more tenders are called and the 1980 construction season starts.

Director of Construction
G. Bourgault, Engineer

Standard Specifications for Construction of Roads and Bridges on Federal Highway Projects

FP-79
1979
U.S. DEPARTMENT OF TRANSPORTATION
Federal Highway Administration

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608.07

If no pay item for Bed Course Material appears in the bid schedule, payment for any bed course material shown on the plans will be considered to be included in the bid price for sidewalk.

Reinforcement, excavation, backfill, disposal of surplus materials, expansion joint material and other related miscellaneous items will not be paid for separately but payment therefor will be included in the bid price of the sidewalk.

Section 609.—CURB AND GUTTER

Description

609.01 This work shall consist of the construction or resetting of curb, gutter or combination curb and gutter in accordance with these specifications and in reasonably close conformity with the lines and grades shown on the plans or established by the Engineer.

Materials

609.02 Materials. Except as provided below the materials used shall meet the requirements of the following subsections:

Stone curbing	712.04
Precast concrete curbing	712.05
Bed course material	703.16
Joint filler	705.01
Reinforcing steel	709.01
Joint mortar	705.02

Concrete for curbing shall be Class A(AE) meeting the requirements of Section 552.

The Engineer may adjust the aggregate size and proportions within the total specified weight as necessary to obtain concrete of a consistency that can be finished to the desired surfaces.

Bituminous mixtures for curbing shall be as specified in the special provisions.

Concrete, bituminous mixes and manufactured curbing materials will be subject to inspection and tests at the plants for compliance with quality requirements.

Concrete curbs, gutters, or curbs and gutters may be cast-in-place, precast or extruded as specified in the contract.

Construction Requirements

609.03 Stone Curbing.

(a) *Excavation.*—Excavation shall be made to the required depth, and the base upon which the curb is to be set shall be compacted to an even surface. All soft and unsuitable material shall be removed and replaced with suitable material which shall be thoroughly compacted.

(b) *Installation.*—The curb shall be set so that the face and top lines conform to the line and grade required. All spaces under the curbing shall be filled with material conforming to the requirements of the material for bed course. This material shall be thoroughly tamped.

The stones shall be cleaned thoroughly and wetted immediately before being set.

(c) *Joints.*—Curbing shall be laid with joints as close as possible for stone curb. These joints shall be filled with mortar as specified.

In those cases where a portland cement concrete pavement is to be constructed contiguous to a curbing, joints shall be constructed in the curbing directly in line with pavement expan-

sion joints. The joint in the curb shall be $\frac{3}{4}$-inch in width and shall be filled with an expansion joint filler of the same nominal thickness as the pavement joint. Any voids between the joint filler and the stone curb shall be filled with mortar.

(d) *Backfilling.* – After the curb has set, any remaining excavated areas shall be filled with approved material. This material shall be placed and thoroughly tamped in layers not exceeding 6 inches in depth.

712.04 Stone Curbing.

(a) *Stone curb.* – The stone for the stone curb items shall conform to the size and shape specified and shall also conform to the following requirements:

Stone curb shall be approved limestone, sandstone or granite from acceptable sources. Stone shall be of the material indicated in the contract, or, if none is indicated, it may be any one of the three at the Contractor's option, provided that only one of the varieties of stone shall be supplied for the project. The exposed faces of stone curb shall be free from drill holes.

All vertical stone curb shall have a top surface sawed or pointed to an approximate true plane with no depression or projection on that surface of over $\frac{1}{4}$-inch. The front and back arris lines shall be pitched straight and true. There shall be no projection or depression on the back surface which would exceed a batter of one inch horizontal on 3 inches vertical.

The front exposed face vertical stone curb shall be sawed, pointed or smooth quarry split, as specified on the plans for the type specified, and shall be formed to an approximately true plane. The remaining face distance shall have no projections or depressions greater than one inch from the plane of the exposed face noted above.

The ends of vertical stone curb shall be square with the plans of the top, back and face, and so finished that when the sections are placed end to end as closely as possible, no space more than $\frac{1}{2}$-inch shall show in the joint for the full width of the top surface and for the entire exposed front face. The remainder of the end may break back no more than 4 inches from the plane of the joint. The joints of circular or curved stone curb shall be cut on radial lines.

The minimum length of any segment of vertical stone curb shall be 4 feet unless otherwise noted on the plans. When required for driveways, crossings, closures or for other reasons, a depressed or modified section of curb is indicated on the plans or ordered by the Engineer, the Contractor shall furnish curbing with the required modification.

(b) *Slope stone curb.* – Unless otherwise indicated on the plans, slope stone curb shall conform to the requirements for stone curb except as follows:

The maximum allowable projection or depression on a horizontal top surface shall be $\frac{1}{2}$ inch on other exposed faces the maximum allowable projection or depression shall be one inch.

For unexposed surfaces the maximum allowable projection or depression from a true plane on a 2-foot length shall be 3 inches.

The maximum allowable space showing on exposed faces between adjacent segments of slope stone curb shall be $\frac{3}{4}$ inch.

The minimum length of any segment of slope stone curb shall be 2 feet.

712.05 Precast Concrete Curbing. Precast concrete curbing shall consist of precast portland cement concrete curb units constructed to the lengths, shapes, and other details shown on the plans. These units shall be reinforced with steel reinforcement when shown on the plans. Steel reinforcement shall conform to subsection 709.01. Concrete shall be class A(AE) conforming to section 552 unless otherwise shown on the plans.

When required for driveways, crossings, closures, or for other reasons, a depressed or modified section of curb is indicated on the plans or ordered by the Engineer, the Contractor shall furnish curbing with the required modification.

712.06 Precast Concrete Units. These units shall be cast in substantial permanent steel forms. Structural concrete used shall attain a minimum 28-day compressive strength of 3000 psi as determined in accordance with AASHTO T22 (ASTM C39). When air entrained concrete is specified, it shall have an air content of 6 percent plus or minus 2 percent by volume. The precast units shall be cured in accordance with AASHTO M170. Water absorption of individual cores taken from such units when tested in accordance with AASHTO T33 shall not

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M9.04.9

M9.04.4 Field Stone Masonry.

Stone for field stone masonry shall consist of sound durable blasted or field stone free from seams, cracks and other structural defects and of an approved and satisfactory quality and shape.

The stone shall have straight edges without re-entrant angles. The faces shall be flat but not necessarily rectangular in shape.

Individual stone shall have, when set in the wall, no face dimension less than 8 inches. Stretchers shall have a depth in the wall at least 1 ½ times the rise, and a length on the face at least twice the rise. Headers shall have a length on the face at least equal to the rise. Headers shall hold in the heart of the wall the same size as shown on the face and shall extend at least 12 inches more than the stretchers into the backing.

When Field Stone Masonry in Cement Mortar is specified mortar shall conform to the requirements of Subsection M4.02.15.

M9.04.5 Granite Curb Inlets.

The granite for curb inlet shall conform to M9.04.0. It shall have a horizontal bed and the top shall be free from wind. The stone shall be sawn or peen hammered on top and the front and back edges shall be pitched true to line. The back face for a distance of 3 inches down from the top shall have no projection greater than 1 inch. The front face shall be straight split, free from drill holes, and it shall have no projection greater than 1 inch or depression greater than ½ inch for a distance of 10 inches down from the top, and for the remaining distance there shall be no depression or projection greater than 1 inch. The ends shall be squared with the top for the depth of the face finish and so cut that the curb inlet can be set with joints of not more than ½ inch.

The granite curb inlet shall be 6 feet in length, plus or minus ½ inch, from 17 to 19 inches in depth, 6 inches wide at the top and at least 6 inches wide at the bottom.

Curb inlets to be set on a radius of 160 feet or less shall be cut to the curve required, unless otherwise directed by the Engineer. The joints of all curved curb inlets shall be cut on radial lines.

A gutter mouth at least 3 inches in depth and at least 2 feet in length shall be cut in the front face of the stone as shown on the plans.

Granite curb inlets shall match the adjacent curbing in color.

M9.04.6 Granite Curb Corners.

The granite for curb corners shall conform to M9.04.0 and shall have horizontal beds. They shall match the adjacent curbing in size, color and quality. The front arris line shall extend through ¼ of a circle having a radius of 2 feet or 3 feet respectively for Type A or Type B Curb Corner. The back arris line shall be straight. The plane of back shall be normal to top.

M9.04.8 Granite Bounds.

Granite bounds shall be of sound granite, the top and bottom faces parallel and the front and back shall be straight split. The bounds shall be cut to the dimensions shown on the plans and shall be plain or lettered as indicated on the plans or as directed.

The stone shall be pointed on the top and on three sides and hammer dressed on the face for a distance of not less than 12 inches below the top. The top shall be 6 inches square and shall have a drill hole in the center 1 ½ inch in depth and ½ inch in diameter, with the bottom somewhat flared.

M9.04.9 Dry Stone Masonry.

Stone for dry stone masonry shall be hard and durable and free from seams or other imperfections and of an approved quality and shape. No stone shall be less than 6 inches in its least dimension. The stone shall be roughly square on joint beds and faces.

M9.04.2

Finish.

Type SA Edging. The exposed face shall be smooth quarry split to an approximately true plane having no projections or depressions which will cause over 1 inch to show between a 2-foot straight-edge and the face when the straight-edge is placed as closely as possible on any part of the face.

If projections on the face are more than that specified they shall be dressed off. The top and bottom lines of the face shall be pitched off to a straight line and shall not show over ½ inch between stone and straight-edge when straight-edge is placed along the entire length of the top and bottom lines and when viewed from a direction at right angles to the plane of the face, and for the top line only not over ½ inch when viewed from a direction in the plane of the face. The ends shall be square to the length at the face and so cut that when placed end to end as closely as possible no space shall show in the joint at the face of over ¾ inch, except that where the edging is to be used on a curve having a radius of 10 feet or less the ends of the stones shall be so cut as to provide a finished joint at the face of not more than ½ inch. The arris formed by the intersection of the plane of the face with the plane of the end joint shall not vary from the plane of the face or the plane of the joint more than ¼ inch. Drill holes may show on the exposed face but only along the bottom edge. The sides shall not be broken under the square more than 4 inches and the side adjacent to the grass shall not project over 1 inch.

Type SB Edging. The exposed face shall be smooth quarry split to an approximately true plane having no projections or depressions which will cause over 1 inch to show between a 2 foot straight-edge and the face when the straight-edge is placed as closely as possible on any part of the face.

If projections on the face are more than that specified they shall be dressed off. The top and bottom lines of the face shall be pitched off to a straight line and shall not show over 1 inch between stone and straight-edge when straight-edge is placed along the entire length of the top and bottom lines and when viewed from a direction at right angles to the plane of the face, and for the top line only not over 1 inch when viewed from a direction in the plane of the face. The ends shall be square to the length at the face and so cut that when placed end to end as closely as possible, no space shall show in the joint at the face of over 1 ½ inches, except that where the edging is to be used on a curve having a radius of 10 feet or less the ends of the stones shall be so cut as to provide a finished joint at the face section of not more than ½ inch. The arris formed by the intersection of the plane of the face with the plane of the end joint shall not vary from the plane of the face more than ¼ inch. Drill holes not more than 3 ½ inches in length and ½ inch in depth will be permitted. The sides shall not be broken under the square more than 4 inches and the side adjacent to the grass shall not project over 1 inch.

Type SC Edging. The exposed face shall be smooth quarry split to an approximately true plane having no projections or depressions which will cause over ½ inch to show between a 2 foot straight-edge and the face when the straight-edge is placed as closely as possible on any part of the face. If projections on the face are more than that specified they shall be dressed off. The top and bottom lines of the face shall be pitched off to a straight line and shall not show over 1 inch between stone and straight-edge when straight-edge is placed along the entire length of top and bottom lines and when viewed from a direction at right angles to the plane of the face, and for the top line only, not over 1 inch when viewed from a direction in the plane of the face. The ends shall be square to the length at the face and so cut that when placed end to end as closely as possible no space shall show in the joint at the face of over 1 ½ inches, except that where the edging is to be used on a curve having a radius of 10 feet or less the ends of the stones shall be so cut as to provide a finished joint at the face of not more than ½ inch. The arris formed by the intersection of the plane of the face with the plane of the end joint shall not vary from the plane of the face more than ¼ inch. Drill holes not more than 3 ½ inches in length and ½ inch in depth will be permitted. The sides shall not be broken under the square more than 4 inches and the side adjacent to the grass shall not project over 1 inch.

M9.04.2

Finish

The finish and surface dimensions for the several types of curb shall conform to the following requirements:

A. Type VA Curb. This type of curbstone shall have a top surface free from wind, shall be peen hammered or sawed to an approximately true plane, and shall have no projections or depressions greater than ⅛ inch. The front and back arris lines shall be pitched straight and true and there shall be no projection on the back surface for 3 inches down from the top which would exceed a batter of 4 inches in 1 foot, except on VA5 the back surface shall have no projection or depression greater than 1 ½ inches.

The front face shall be at right angles to the planes of the top and ends and shall be smooth quarry split, free from drill holes and with no projection of more than 1 inch and no depression of more than ½ inch measured from the vertical plane of the face through the arris or pitch line for a distance down from the top of 8 inches for types VA1 and VA4, 10 inches for VA2 and VA3, and the full depth of VA5. For the remaining distance there shall be no projection or depression greater than 1 inch measured in the same manner.

The ends of all stones shall be square with the planes of the top and face so that when the stones are placed end to end as closely as possible no space shall show in the joint at the top and face of more than ½ inch for the full width of the top and for 8 inches down on the face for Type VA1 and VA4, 10 inches for VA2 and VA3, and the full depth of VA5; after which the end may break back not over 8 inches from the plane of the joint. The arris formed by the intersection of the plane of the joint with the planes of the top and exposed faces shall have no variation from the plane of the top and exposed faces greater than ⅛ inch.

B. Type VB Curb. This type of curbstone shall have a top surface free from wind, shall be pointed, peen hammered or sawed to an approximately true plane and shall have no projections or depressions greater than ¼ inch. The front and back arris lines shall be pitched straight and true.

The front face shall be at right angles to the plane of the top, and shall be smooth quarry split, free from drill holes and with no projection of more than 1 ½ inches and no depression greater than 1 inch measured from the vertical plane of the face through the arris or pitch lines for the full depth of the face.

The ends of all stones shall be square with the planes of the top and face so that when stones are placed end to end as closely as possible no space shall show in the joint in the top and face of more than ½ inch for the full width of the top and 8 inches down on the face after which the ends may break back not more than 1 foot from the plane of the joint. On pieces less than 4 feet in length, the ends shall not break back more than 9 inches. The arris formed by the intersection of the plane of the joint with the planes of the top and exposed faces shall have no variation from the plane of the top and exposed faces greater than ⅛ inch.

M9.04.2 Granite Edgestone.

The stones for the several types of edging shall be cut to the dimensions given in the following table:

	Type SA	Type SB	Type SC
Minimum Length	3′	2′	1′
Maximum Length	6′	6′	6′
Thickness	5″ to 8″	3″ to 6″	3″ to 6″
Width of Face	12″	11″ to 13″	11″ to 13″

When the edging is used on a curve of 160 foot radius or less the length shall be as directed by the Engineer except that where the edging is to be set on a radius of 10 feet the maximum length shall be 1 foot.

Active Ingredients:		
Methoxychlor, Technical		25%
Xylene		70%
Inert Ingredients		5%
	Total	100%

The 25% concentrate shall contain not less than 76.4 milligrams of chlorine per gram when tested in accordance with Standard Department test methods.

M9.04.0 Curb and Edging.

All granite curb and edging shall be basically light gray in color, free from seams and other structural imperfections or flaws which would impair its structural integrity, and of a smooth splitting appearance. Natural color variation characteristic of the deposit from which the curbing is obtained will be permitted.

Whenever curbing is sawed, all surfaces that are to be exposed shall be thoroughly cleaned and any iron rust or iron particles removed by sand blasting or other approved methods satisfactory to the Engineer and any saw mark in excess of ⅛ inch shall be removed.

M9.04.1 Granite Curb.

The stones for the several types of granite curb shall be cut to the dimensions and curvature hereinafter stated:

Type	Min. Length	Width at Top	Depth	Minimum Width at Bottom
VA1	6 feet	7 in.	17-19 in.	4 in. (for 2/3 length)
VA2	6 feet	7 in.	19-21 in.	4 in. (for 2/3 length)
VA3	6 feet	6 in.	19-21 in.	4 in. (for 2/3 length)
VA4	6 feet	6 in.	17-19 in.	4 in. (for 2/3 length)
VA5	6 feet	6 in.	See Plans	5 in. (for 2/3 length)
VB	3 feet	5 in.	15-17 in.	3½ in. (for 2/3 length)

Except for the two (2) following special conditions, ten percent (10%) of the length of each type of VA curb installed on the project may consist of stones no more than six inches (6") shorter than the length specified in either table.

(1) Stones used in making closures may be as much as one third shorter than specified in either table.

(2) On curves with radii greater than 100 feet but less than 500 feet, type VA stones may be from four feet (4') to *not more than six feet* (6') *in length.*

Type VA stones to be set on a radius of 100 feet or less shall be cut to the required curvature unless otherwise directed and except for making closures shall be of minimum lengths as follows:

Radius	Minimum Length
50 feet to 100 feet	6 feet
25 feet to less than 50 feet	4 feet 6 inches
Less than 25 feet	3 feet

Type VB stones to be set on a radius of 100 feet or less shall be cut to the required curvature unless otherwise directed.

The ends of all curved stones shall be cut on radial lines.

SECTION 8.13
STONE CURBING

8.13.01—Description: This curbing shall consist of approved stone, furnished in accordance with the dimensions and details of the plans, or as ordered, and installed on the prepared base to the lines and grades given and in conformity with these specifications.

8.13.02—Materials: The materials for this work shall conform to the requirements of Article M.12.06 for granite curbing, of Article M.12.06 for bluestone curbing, of Article M.11.04 for mortar and of Article M.02.03 for gravel base.

8.13.03—Construction Methods: Construction methods for stone curbing shall conform to the following requirements:

1—Excavation: Excavation shall be made to the bottom of the 6-inch gravel base below the curbing, the trench being sufficiently wide to permit thorough tamping. The base shall be compacted to a firm, even surface and shall be approved by the Engineer.

2—Installing Stone Curbing: The curbing shall be set on edge and settled into place with a heavy wooden hand-rammer, to the line and grade required, straight and true for the full depth. The joints of the stone curbing shall be pointed with mortar for the full depth of the curbing. At approximately 50-foot intervals, a ½-inch joint shall not be filled with mortar but left free for expansion. The ends of the stone curbing at driveways and intersections shall be cut at a bevel or rounded, as directed by the Engineer.

3—Backfilling: The trench for the stone curbing shall be backfilled with approved material; the first layer to be 4 inches in depth, thoroughly rammed; the other layers to be not more than 6 inches in depth and thoroughly rammed until the trench is filled.

4—Openings: Where indicated on the plans, or directed, drainage openings shall be made through the curbing at the elevations and of the size required.

8.13.04—Method of Measurement: This work will be measured for payment by the actual number of linear feet of stone curbing or curved stone curbing installed and accepted. Measurement shall be made along the top arris line of face of curb. Curbing to be set on a radius of 100 feet or less will be measured for payment as curved stone curbing.

8.13.05—Basis of Payment: Payment for this work will be made at the contract unit price per linear foot for "Stone Curbing" or "Curved Stone Curbing," as the case may be, of the type, size and kind specified, complete in place, which

price shall include all materials, equipment, tools and labor incidental thereto, and all excavation, backfilling, disposal of surplus material and all drainage openings.

There will be no direct payment for furnishing, placing and compacting gravel base, beveling or rounding the ends of the curbing and pointing the joints with mortar, but the cost of this work shall be considered as included in the general cost of the work.

Pay Item	Pay Unit
Stone Curbing (Type-Size)	L.F.
Curved Stone Curbing	L.F.

SECTION 8.14
RESET STONE CURBING

8.14.01—Description: This work shall consist of the removing and resetting or adjusting of existing stone curbing to the lines and grades given, in accordance with the dimensions and details of the plans or as ordered and in conformity with these specifications.

8.14.02—Materials: All existing curbing which is acceptable shall be used. The reset stone curbing shall be in lengths of not less than 4 feet, except where necessary for closures, where no piece shall be less than 3 feet in length. Mortar for this work shall conform, as regards materials, proportions and mixing, to the mortar specified in Article M.11.04.

8.14.03—Construction Methods: The construction methods for this work shall conform to the requirements of Article 8.13.03 for stone curbing, as supplemented by the following requirements:

The curbing to be reset shall be removed with care to avoid damage and, if ordered, shall be transported to a point or points on the project which will allow all the reset curbing to be installed in continuous lines. Curbing removed and not reset shall remain the property of the State unless otherwise ordered by the Engineer, and shall be transported to such points, adjacent to the work, as the Engineer may designate. Where adjustments only have to be made to curbing, such adjustments shall be carried out as specified by the Engineer.

8.14.04—Method of Measurement: This work will be measured for payment by the actual number of linear feet of the class of curbing, reset and accepted.

8.14.05—Basis of Payment: Payment for this work will be made as follows:

This work will be paid for at the contract unit price per linear foot of reset curbing (type-size), complete in place, which price shall include all materials, equipment, tools and labor incidental thereto and all excavation, backfilling, disposal of surplus material and all drainage openings.

There will be no direct payment for furnishing, placing and compacting gravel base, beveling or rounding the ends of the curbing, sealing the joints with mortar, removing the curbing and hauling it to any location on or adjacent to the project as directed by the Engineer; but the cost of this work shall be considered as included in the general cost of the work.

Pay Item	Pay Unit
Reset Curbing (Type-Size)	L.F.

SECTION 8.15
BITUMINOUS CONCRETE LIP CURBING

8.15.01—Description: Bituminous concrete lip curbing shall consist of machine laid bituminous concrete, constructed on the pavement to the dimensions and details shown on the plans, or as ordered, and in conformity with the specifications.

8.15.02—Materials: Materials for this work shall conform to the requirements of Article M.04.01, Class 3.

8.15.03—Construction Methods: The provisions of Article 4.02.03 shall govern, except that the requirements pertaining to samples and density, will not apply. In addition, the curbing shall be constructed in accordance with the following requirements: Prior to the arrival of the mixture on the work, the surface of the pavement where the curbing is to be constructed shall be cleaned of all loose and foreign material. The surface, which shall be perfectly dry and clean at the time the mix is placed, shall be coated with an RC-250 or other approved bitumen just prior to placing the mixture.

On arrival at the site, the mixture shall be transferred from the truck to the hopper of the curbing machine; and the mixture shall be kept clean and free from dirt or foreign materials at all times.

The surface of the curbing shall be tested with a 10-foot straightedge, and any variation from a true line exceeding ¼ inch shall be satisfactorily corrected. The only compaction

required shall be that obtained by the approved mechanical curbing machine.

Where machine work is impractical, the Engineer may permit hand-laid curbing to be constructed.

If the design of the curbing machine is such that the outside wheels operate outside of the curb, the Contractor will be required to obtain a smooth surface by grading and consolidating the area on which the outside wheel of the machine rides, and this work shall be done at his expense.

After the completion of curbing, traffic shall be kept at a safe distance for a period of not less than 24 hours and until the curbing has set sufficiently to prevent injury to the work.

8.15.04—Method of Measurement: This work will be measured for payment along the top of the curb and will be the actual number of linear feet of bituminous concrete lip curbing completed and accepted.

8.15.05—Basis for Payment: This work will be paid for at the contract unit price per linear foot for "Bituminous Concrete Lip Curbing" complete in place, which price shall include all materials, equipment, tools and labor incidental thereto.

Pay Item	Pay Unit
Bituminous Concrete Lip Curbing	L.F.

SECTION 8.16
GRANITE SLOPE CURBING

8.16.01—Description: Granite slope curbing shall consist of approved granite furnished in accordance with the dimensions and details of the plans, or as ordered, and installed on the prepared base to the lines and grades given and in conformity with these specifications.

8.16.02—Materials: The materials for this work shall conform to the requirements of Articles M.12.07 for granite slope curbing, M.11.04 for mortar, M.02.03 for gravel base and M.03.01-8 for joint seal.

8.16.03—Construction Methods: Construction methods for granite slope curbing shall conform to the following requirements:

1—Excavation: Excavation shall be made of sufficient depth and width to accommodate the gravel base as shown on

the plans. The gravel fill base shall be compacted to a firm, even surface and shall be approved by the Engineer.

2—Gravel Fill Base: The gravel fill base for the granite slope curbing shall be placed in layers not to exceed 6 inches in depth, loose measurement, and thoroughly rammed.

3—Installing Granite Slope Curbing: The curbing shall be set as shown on the typical section and settled into place with a heavy wooden rammer to the line and grade required, straight and true for the full depth. The top line of the curbing shall be set straight and true, allowing natural variations in depth of curbing to occur at the bottom of the face. The joints of the stone curbing shall be pointed with mortar for the full depth of the curbing. At approximately 50-foot intervals, a ½-inch joint shall not be filled with mortar but left free for expansion.

When the slope curbing is set adjacent to concrete surfaces, it shall be set as shown on the plans. The joint between the concrete surface and the slope curbing shall then be sealed flush with the surface of the concrete. At the time of sealing the joint, the concrete, the stone curbing and the joint area shall be clean and dry to the depth specified for placement of the seal material.

When the slope curbing is to be placed adjacent to surfaces other than concrete, the curbing shall be set before the final surfacing is placed.

4—Openings: Where indicated on the plans, or directed by the Engineer, details of curbing shall be adjusted as ordered to provide for drainage openings.

8.16.04—Method of Measurement: This work will be measured for payment by the number of linear feet of granite slope curbing or curved granite slope curbing actually installed and accepted, measured along the top arris line of face of curb. Only curbing placed on a radius of less than 10 feet will be measured for payment as curved granite slope curbing.

8.16.05—Basis of Payment: Payment for this work will be made at the contract unit price per linear foot for "Granite Slope Curbing" or "Curved Granite Slope Curbing," as the case may be, complete in place, which price shall include all materials, equipment, tools and labor incidental thereto, and all excavation, backfilling and disposal of surplus material.

There will be no direct payment for furnishing, placing and compacting gravel base, pointing the joints with mortar and sealing the longitudinal joint, but the cost of this work shall be considered as included in the general cost of the work.

Pay Item	Pay Unit
Granite Slope Curbing (Size)	L.F.
Curved Granite Slope Curbing (Size)	L.F.

SECTION 8.17
GRANITE STONE CURBING FOR BRIDGES

8.17.01—Description: This curbing shall consist of approved granite stone, furnished in accordance with the dimensions and details shown on the plans, or as ordered, and installed to the lines and grades given and in conformity with these specifications.

8.17.02—Materials: The materials for this work shall conform to the requirements of Article M.12.08.

8.17.03—Construction Methods: Granite stone curbing shall be constructed in the location and to the dimensions shown on the plans. The stone curbing shall be accurately set, straight and true to the line and grade as required. The stone curbing shall be set in a full mortar bed and full mortar end joints. As the stone curbing is being set, the anchors shall be grouted into the holes in the curbing by a method as approved by the Engineer. The concrete backing shall not be placed until the curbing and anchors have been properly placed. Care must be taken to prevent any movements of the stone curbing already in place while placing and compacting concrete backing. When required by the Engineer, the stone curbing shall be supported by such bracing and form work as may be necessary to prevent movement. Where vertical contraction joints or vertical expansion joints, or both, exist in the backing, the vertical joint of the curb shall coincide with the contraction or expansion joint.

All mortar joints shall be finished smooth and flush. These joints shall be carefully filled with cement mortar and shall be neatly pointed on the top and exposed front portions. After pointing, stone curbing shall be cleaned of all excess mortar to the satisfaction of the Engineer.

Where required and indicated on the plans, joint seal shall be placed in accordance with the provisions of Article 4.01.03-11 (g) insofar as it may apply.

Where indicated on the plans, or directed, drainage open-

ings shall be made through the curbing at the elevations and of the size required.

8.17.04—Method of Measurement: This work will be measured for payment by the actual number of linear feet of granite stone curbing for bridges or curved granite stone curbing for bridges as the case may be, of the various sizes, installed and accepted. Measurement shall be made along the top arris line of the face of the curb. Stone curbing set on a radius of 160 feet or less will be measured for payment as curved granite stone curbing for oridges.

8.17.05—Basis of Payment: Payment for this work will be made at the contract unit price per linear foot for "Granite Stone Curbing for Bridges" or "Curved Granite Stone Curbing for Bridges," as the case may be, of the various sizes specified, complete in place, which price shall include all materials including anchors, equipment, tools and labor incidental thereto.

There will be no direct payment for the cost of drilling holes in stone curbing for anchors, beveling or rounding the ends of the stone curbing and pointing the joints with mortar, and sealing the longitudinal joint; but the cost of this work shall be considered as included in the general cost of the work.

Pay Item	Pay Unit
Granite Stone Curbing for Bridges (Size)	L.F.
Curved Granite Stone Curbing for Bridges (Size)	L.F.

SECTION 8.18
PROTECTIVE COMPOUND FOR BRIDGES

8.18.01—Description: Under this item, the Contractor shall furnish and apply uniformly a protective compound to the exposed concrete surfaces of bridges, decks, box culverts, curbs, sidewalks, inside face of parapets, exposed tops of backwalls of bridges, tops of abutment bridge seats and tops of piers, as indicated on the plans or ordered by the Engineer.

8.18.02—Materials: The material for this work shall conform to the requirements of Article M.03.01-11.

8.18.03—Construction Methods: Before this work is undertaken, surfaces to receive the protective compound shall have been finished in accordance with the requirements of the

ing to above specified requirements, to which has been added 20 percent, by weight, of asbestos fiber. The incorporation of the asbestos fiber with the asphalt shall be done at the factory of the manufacturer to insure a uniform distribution of the fiber throughout the mix.

M.12.05—Dampproofing: The materials for this work shall conform to the following requirements:

Asphalt for primer and Seal Coat: Asphalt for primer shall conform to the requirements of AASHO M116. Asphalt for the seal coat shall conform to the requirements of AASHO M115 Type A.

Tar for Primer and Seal Coat: The seal coat shall conform to the requirements of AASHO M 52, Grade RTCB-5. The primer shall be a liquid water-gas tar which shall conform to the following requirements:

Specific gravity 25°/25°C. (77°/77°F.)	1.030 to 1.100
Specific viscosity at 40°C. (104°F.) (Engler) not more than	3.0
Total distillate by weight, to 300°C. (572°F.) not more than	50.0
Bitumen (soluble in carbon disulphide) not less than	98.0%
Water, not less than	3.0%

M.12.06—Stone Curbing: The materials for this work shall conform to the following requirements:

1—Granite Curbing: Stone for this work shall be hard and durable granite, fundamentally of light color, of general uniform texture, of smooth splitting appearance, free from seams or imperfections that would impair its structural reliability and containing only such color variations as in the opinion of the Engineer would reasonably be characteristic of the material source. The Contractor shall submit for approval the name of the quarry and the type of curb which the Contractor proposes to use; samples of curbing shall be submitted for approval only when requested by the Engineer. Such submission shall be made sufficiently in advance of ordering so that the Engineer may have an opportunity to judge the stone, both as to quality and appearance. No stone from any other quarry shall be used unless it has been properly approved.

The finish and surface dimensions for the curb shall conform to the following requirements:

The curbstone shall have a top surface free from wind; it shall be pointed, peen-hammered or sawed to an approximately true plane, and shall have no projections or depressions greater than $\frac{1}{8}$ of an inch. The front and back arris lines shall be pitched straight and true.

On the back surface of the curbstone there shall be no projection for 3 inches down from the top which would fall outside of a plane having a batter of 4 inches in 12 inches from the back arris line.

The front face shall be at right angles to the plane of the top and shall be smooth quarry-split, free from drill holes in the exposed face. There shall be no projections greater than $\frac{3}{4}$ of an inch, or depressions greater than $\frac{1}{2}$ inch, measured from the vertical plane of the face through the top arris line for a distance of 8 inches down from the top. For the remaining distance, there shall be no projections or depressions greater than 1 inch measured in the same manner. The arris lines at the ends shall be pitched with no variation from the plane of the face greater than $\frac{1}{8}$ of an inch.

The ends of all stones shall be square with the planes of the top and face and so finished that, when the stones are placed end to end as closely as possible, no space more than $\frac{1}{2}$ inch shall show in the joint for the full width of the top or down on the face for 8 inches. On curbstones having a length of 6 feet or more, the remainder of the end may break back not over 9 inches, whereas on shorter curbstones, they shall not break back more than 6 inches.

If sawed, the curbstones shall be thoroughly cleaned of any iron rust or iron particles.

For straight curbing, 80 percent of the stones shall be furnished in lengths of not less than 6 feet, and the remaining 20 percent in lengths of not less than 4 feet, interspersed at random, to allow for closures.

Curbstones to be set on a radius of 100 feet or less shall be cut to the curve required, and their ends shall be cut on radial lines. Requirements for length of individual stones in curved curbing vary with radii of curves.

2—Bluestone Curbing: Stone for this work shall be of a good grade, free from structural defects, and shall be approved by the Engineer.

It shall conform to the requirements contained hereinbefore for granite curbing, except that the top surface and the top 8 inches of the front face shall be "fine-pointed" in conformity with the requirements of Article M.11.01 for masonry facing stone.

3—Mortar: The mortar for this work shall conform to Article M.11.04.

4—Gravel Base: The gravel base under the stone curbing shall be gravel fill conforming to Article M.02.01.

M.12.07—Granite Slope Curbing: The materials for this work shall conform to the following requirements:

1—Granite Slope Curbing: Stone for this work shall be hard and durable granite, fundamentally of light color, of general uniform texture, of smooth-splitting appearance, free from seams or imperfections that would impair its structural reliability and containing only such color variations as, in the opinion of the Engineer, would reasonably be characteristic of the material source. The exposed face of all curbing shall be smooth, quarry-split to an approximate true plane, and shall have no projections or depressions which will cause over 1 inch to show between a 2-foot straightedge and the face when the straightedge is placed as closely as possible on any part of the face. If projections on the face are more than that specified, they shall be dressed off. The top arris line at the face shall be pitched to a line which shall not show over 1 inch in any direction between the stone and a straightedge the full length of the stone. The bottom arris line at the face shall be pitched so that not over 1 inch shall show between the stone and a straightedge, the full length of the stone, when viewed at right angles to the plane of the face. The ends shall be square to the plane of the face and so finished that when the stones are placed end to end as closely as possible, no space more than $1\frac{1}{2}$ inches shall show in the joint for the full width of the face. The arris lines at the ends shall be pitched with no variation from the plane of the face more than $\frac{1}{4}$ of an inch. Drill holes not more than $3\frac{1}{2}$ inches in length or $\frac{1}{2}$ inch in depth will be permitted. The sides shall not be under the square more than 4 inches, or over the square at the back more than 1 inch.

The straight slope curbing shall be in lengths of not less than 2 feet. The curved slope curbing shall be in lengths of at least 6 inches. The curbing shall have a minimum thickness of 3 inches and a maximum thickness of 6 inches.

When the slope curbing is set adjacent to concrete pavement or gutters, the width of the face of the curbing shall be 12

inches, with a tolerance of plus or minus ½ inch. When set adjacent to surfaces other than concrete, the curbing finished shall have a face width of not more than 13 inches and not less than 11 inches.

2—Mortar: The mortar for this work shall conform to Article M.11.04.

3—Gravel Base: The gravel base under the slope curbing shall be gravel fill conforming to Article M.02.03.

M.12.08—Granite Stone Curbing for Bridges: The materials for this work shall conform to the following requirements:

1—Granite Curbing: Stone for this work shall be hard and durable granite, fundamentally of light color, of general uniform texture, of smooth-splitting appearance, free from seams or imperfections that would impair its structural reliability, and containing only such color variations as in the opinion of the Engineer would be reasonably characteristic of the material source. When so directed by the Engineer, the Contractor shall submit samples of the type of curb he proposes to use.

The finish and surface dimensions for the curb shall conform to the following requirements:

The curb shall have a top surface free from wind; it shall be pointed, peen-hammered or sawed to an approximately true plane, and shall have no projections or depressions greater than ¼ of an inch. The front and back arris lines shall be pitched straight and true. The bottom surface shall be sawed or split to dimensions with not more than ¼-inch tolerance.

On the back surface of the curb there shall be no projection for 1 inch down from the top greater than ¼ of an inch. The remainder of the back face may fall away not more than 1½ inches and shall be free of any projections which will interfere with the setting.

The front face of the curb shall be at right angles to the planes of the top and ends and shall be smooth, quarry split, free from drill holes. There shall be no projections or depressions of more than ¼ inch, measured from the vertical plane of the face through the top arris line for the full height.

The ends of all stone shall be jointed square with the planes of the top and face and finished smooth except that, if so noted on plans, the extreme end face of the curbing shall be finished to a radius as shown on the plans.

The minimum length of a stone shall be 4 feet, except that stones of lengths less than 4 feet will be so noted on the plans. The maximum length of stone to be used on horizontal and vertical curves shall be such as to produce the effect of a smooth, continuous curve. Curbs to be set on a radius of 160 feet or less shall be cut to the curve required, and their ends shall be cut on radial lines.

Detailed cutting plans or schedule shall be submitted for approval of the Engineer prior to cutting stones.

2—Mortar: The mortar for this work shall conform to Article M.11.04.

3—Metal Anchors: Metal anchors shall be steel conforming to the requirements of Article M.06.01 for bar reinforcement and shall be thoroughly galvanized by the hot-dip process after fabrication.